Synthesis Y. Kiyosu et al. Special Topic

Synthesis of Fused Diaziridine Derivatives from Cyclic Secondary Amines by Utilizing *N*-Bromosulfonamides as an Aminating Reagent

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In memory of Prof. Dr. Kilian Muñiz (1970–2020)

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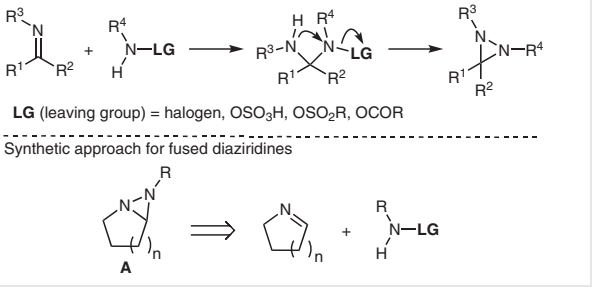
Abstract The synthesis of a series of fused diaziridines, which are difficult to access by existing methods, was achieved by the reaction of cyclic secondary amines with *p*-toluenesulfonamide in the presence of *N*-bromosuccinimide (NBS) and a suitable base. This oxidation system enables the efficient in situ formation of the key intermediates, which are *N*-bromoamines (a precursor of cyclic imines) and *N*-bromosulfonamides. In addition, an alternative method using *N*-bromo-*N*-sodio-*p*-toluenesulfonamide (bromamine-T) in the presence of a catalytic amount of CF_3CO_2H for the synthesis of fused diaziridines is also reported.

Key words cyclic secondary amines, cyclization, diaziridines, *N*-bromosulfonamides, nitrogen-containing heterocyclic compounds

Diaziridines, which contain two nitrogen atoms and one carbon atom, are among the smallest known nitrogen-containing heterocyclic compounds and exhibit some unique chemical and biological properties.[1] Owing to the strained nature of the three-membered ring, diaziridines have unique reactivity. For example, they readily open through either C–N or N–N bond cleavage and are frequently used in dipolar cycloaddition, ring expansion, and alkylation reactions.[2] In addition, they have many applications in the field of medicinal and pharmaceutical chemistry.[3] Because of this, continual efforts have been devoted to the development of new methods for the synthesis of this class of compounds.[4] The most general approach to accessing diaziridines involves the reaction of imines with aminating reagents such as *N*-haloamines, hydroxylamine-*O*-sulfonic acids, or hydroxylamine *O*-esters (Scheme 1).[5] However, despite the advances made in the synthesis of monocyclic diaziridines, methods that enable the formation of fused diaziridines continue to be scarce. Indeed, although there are some examples of the synthesis of diaziridines **A**, a class of fused diaziridines, by the reaction of cyclic imines with chloramine or hydroxylamine-*O*-sulfonic acids, these methods suffer from limited substrate scope and low efficiency.[5a,6] This is mainly because of the instability of cyclic imines, which exist in equilibrium between their monomers and trimers,[7] as well as a lack of suitable aminating reagents.



Scheme 1 A general approach to accessing diaziridines

Our group has been involved in investigations related to oxidative amination reactions, with emphasis on the aziridination of alkenes, by utilizing inexpensive and readily available chloramine salts as aminating reagents that have both a sufficient level of nucleophilicity and electrophilicity.[8] Based on these previous studies, we hypothesized that the unique reactivity of haloamine salts might be used to develop an efficient method for the synthesis of fused diaziridines from cyclic imines. To investigate this hypothesis further, the commercially available *N*-chloro-*N*-sodio-*p*-toluenesulfonamide (chloramine-T) was initially chosen as an aminating reagent for use in the diaziridination of 1-pyrroline (a mixture of monomers and trimers), but no reaction was observed, probably as a result of insufficient nucleo-

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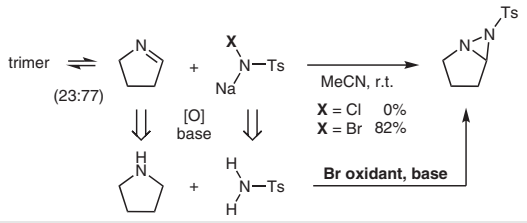
philicity of chloramine-T (Scheme 2). Changing the chlorine atom on the nitrogen atom to a bromine atom was found to enhance the nucleophilicity of the haloamine salt, resulting in the formation of the desired diaziridine in high yield. This promising result encouraged us to develop a more practical process using cyclic secondary amines as substrates and *p*-toluenesulfonamide as the aminating reagent, in the presence of a bromine-based oxidant and a base, which allows the preparation of unstable cyclic imines and *N*-bromo-*N*-sodio-*p*-toluenesulfonamide (bromamine-T) to be avoided.[8b,9]

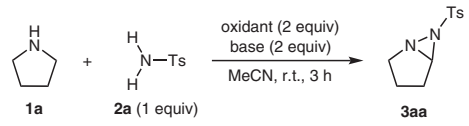


Scheme 2 Synthesis of a fused diaziridine from 1-pyrroline with haloamine salts: Preliminary results and working hypothesis

We then conducted a survey of bromine-based oxidants and bases for the reaction of pyrrolidine (**1a**) with *p*-toluenesulfonamide (**2a**) in MeCN at room temperature (Table 1). The use of *N*-bromosuccinimide (NBS) and NaOH gave the desired diaziridine **3aa** in moderate yield (entry 1). We then evaluated several bases and were pleased to find that K_2CO_3 was effective in this diaziridination and afforded **3aa** in 83% yield, even though the use of Na_2CO_3 resulted in no desired product formation (entries 2 and 3). When 1,3-dibromo-5,5-dimethylhydantoin (DBH) was used (entry 4), **3aa** was also obtained but in a lower yield than that in the reaction using NBS. Meanwhile, no reaction was observed when *N*-chloro- and *N*-iodosuccinimide (NCS and NIS) were used (entries 5 and 6). These results demonstrate that NBS together with K_2CO_3 is a suitable oxidation system for this diaziridination. Slightly increasing the amounts of reagents used improved the yield of **3aa** up to 89% (entry 7).

The reactivity of other amides as the aminating reagent for this diaziridination was evaluated (Scheme 3). Instead of **2a**, highly electron-deficient 2-nitrobenzenesulfonamide (**2b**) was also applicable, affording the corresponding diaziridine in moderate yield. However, carbamates, such as *O*-benzyl or *O*-*tert*-butyl carbamate (**2c** and **2d**), which have a higher nucleophilicity than sulfonamides,[8d] were not effective. This is probably a result of the low conversion of carbamates into the corresponding bromamine salts under the reaction conditions used. These results demonstrate that the use of **2a** was optimal, that **2a** can be readily converted into the corresponding bromamine salt in situ, and that it has sufficient nucleophilicity and electrophilicity to react with a cyclic imine to form a fused diaziridine.

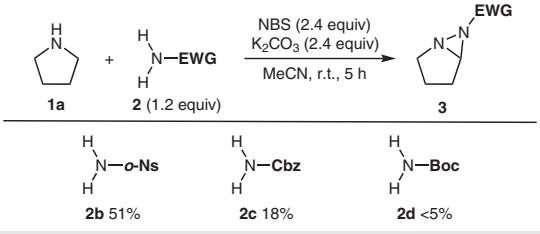
Table 1 Survey of Oxidants and Bases[a]



Entry	Oxidant	Base	Yield (%)[b]
1	NBS	NaOH	59
2	NBS	Na_2CO_3	0
3	NBS	K_2CO_3	83
4	DBH[c]	K_2CO_3	67
5	NCS	K_2CO_3	0
6	NIS	K_2CO_3	0
7[d]	NBS	K_2CO_3	89

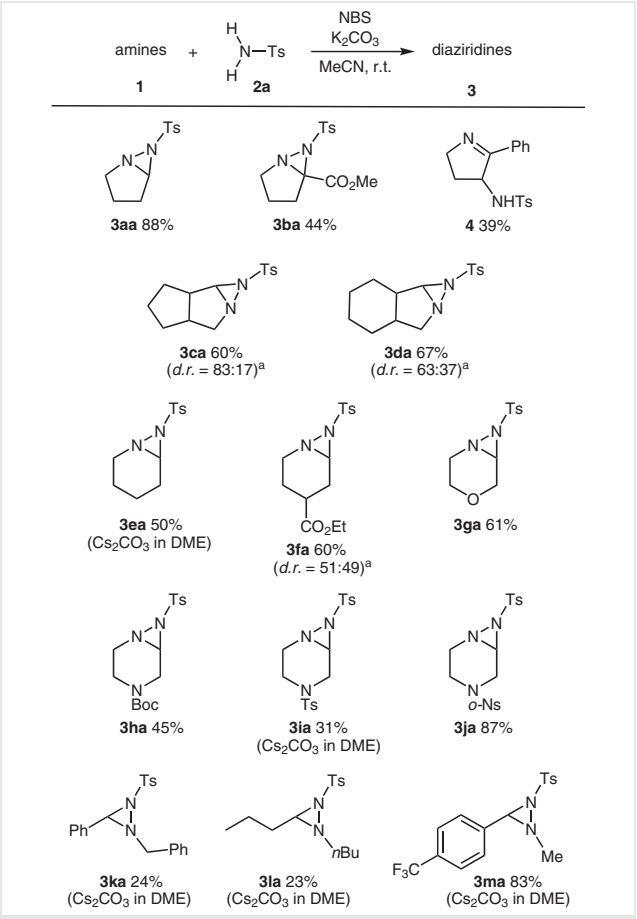
[a] Standard reaction conditions: **1a** (0.5 mmol), **2a** (0.5 mmol), oxidant (1 mmol), base (1 mmol), MeCN (5 mL), r.t., 3 h.
[b] Determined by ^{1}H NMR analysis of the crude product with 1,1,2,2-tetrachloroethane as an internal standard.
[c] DBH (1 equiv) was used.
[d] **2a** (1.2 equiv), NBS (2.4 equiv), and K_2CO_3 (2.4 equiv) were used.

With the simple system using **2a** and NBS/K_2CO_3 for the preparation of diaziridines in hand, the scope of the amines was investigated (Scheme 4). In addition to pyrrolidine (**1a**), methyl pyrrolidine-2-carboxylate was found to be applicable and underwent regioselective diaziridination to form **3ba** in moderate yield. However, when 2-phenylpyrrolidine was used as a substrate, imine **4** was formed instead of the desired diaziridine product. The method was also successfully applied to the synthesis of tricyclic fused diaziridines **3ca** and **3da**. In addition, a series of six-membered nitrogen-containing heterocycles, including piperidines (**3ea**, **3fa**), morpholine (**3ga**), and piperazines (**3ha**, **3ia**, **3ja**), were also suitable substrates. Although piperidine and 1-tosylpiperazine showed low reactivity, extensive screening of bases and solvents revealed that the use of Cs_2CO_3 in 1,2-dimethoxyethane (DME) was effective and provided **3ea** and **3ia**, respectively. By using this system, it was possible to prepare not only fused diaziridines but also monocyclic diaziridines. Dibenzyl amine and di-*n*-butyl amine could be transformed into the corresponding diaziridines **3ka** and **3la**, respectively, albeit in low yields. The site-selective for-

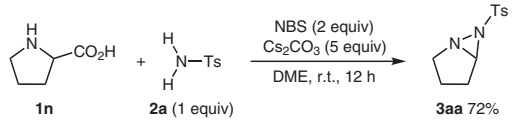


Scheme 3 Effect of the electron-withdrawing group on the nitrogen atom

mation of high yields of **3ma** indicates that diaziridination at an acidic C–H bond is preferred. Interestingly, when DL-proline (**1n**) was used as a substrate, decarboxylative diaziridination proceeded and provided **3aa** in good yield (Scheme 5).[10]



Scheme 4 Substrate scope of amines. *Reagents and conditions*: **1** (0.5 mmol), **2a** (1–1.2 equiv), NBS (2–2.4 equiv), K_2CO_3 or Cs_2CO_3 (2–5 equiv), MeCN or DME (5 mL), r.t., 12 h. Yields are isolated yields.
[a] Determined by ^{1}H NMR analysis of the crude product.

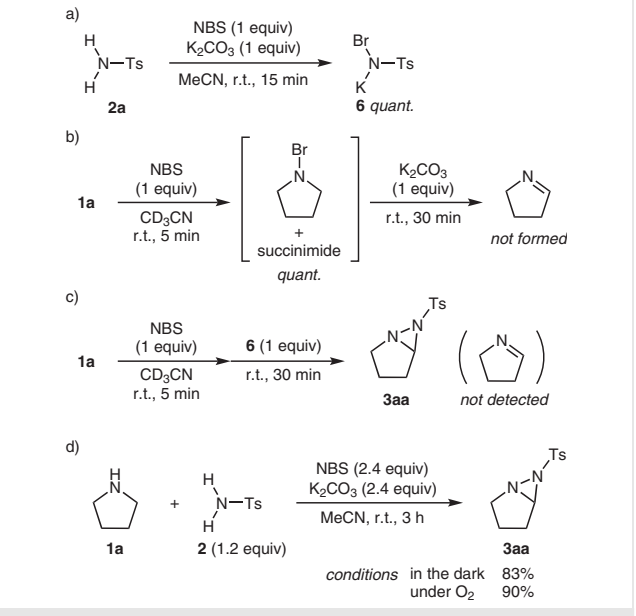


Scheme 5 Decarboxylative diaziridine synthesis from DL-proline

The tosyl group of the fused diaziridine product could be removed without the decomposition of the diaziridine skeleton. Diaziridine **3ha** was treated with magnesium in the presence of a catalytic amount of iodine in MeOH to afford N–H diaziridine **5** (Scheme 6),[5e] indicating that such diaziridine derivatives can be further elaborated.

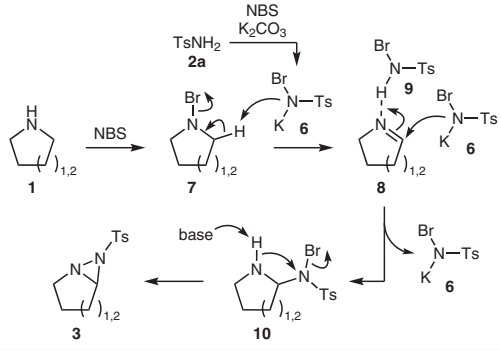
Scheme 6 Removal of the tosyl group from a diaziridine product

We performed several experiments to gain additional insights into the reaction mechanism (Scheme 7). First, to determine whether a bromamine salt is generated under the reaction conditions, **2a** was mixed with an equimolar amount of NBS and K_2CO_3 in MeCN at room temperature. In the mixture, **2a** was consumed within 15 min, and quantitative formation of bromamine salt **6** was observed (Scheme 7a).[9] Treatment of **1a** with NBS led to a downfield shift in the signals corresponding to **1a** and quantitative formation of succinimide, which strongly indicates that the N–H bromination of **1a** occurred to provide an *N*-bromopyrrolidine species (Scheme 7b). However, subsequent addition of K_2CO_3 to the mixture did not give the corresponding cyclic imine. Meanwhile, the use of bromamine salt **6**, instead of K_2CO_3, resulted in the smooth conversion of *N*-bromopyrrolidine to diaziridine **3aa**, with no cyclic imine observed (Scheme 7c). These results indicate that **6**, and not K_2CO_3, functions as a base to provide a cyclic imine, which then rapidly reacts with the remaining **6** to form **3aa**. When the reaction was carried out either in the dark or under an O_2 atmosphere, it proceeded as efficiently as under the standard conditions (under N_2 in the presence of a fluorescent light), suggesting that the reaction does not involve a radical process (Scheme 7d).



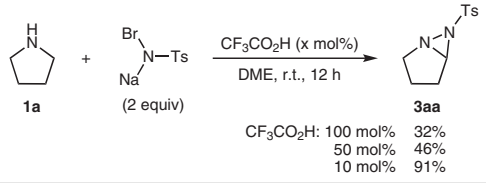
Scheme 7 Mechanistic investigations

Based on the experimental results, a proposed reaction pathway is shown in Scheme 8. The cyclic secondary amine **1** initially reacts smoothly with NBS, generating *N*-bromoamine **7**. The bromamine salt **6**, which is generated by the reaction of **2a** with NBS/K_2CO_3 in situ, then abstracts a proton from **7** to give cyclic imine **8**. Subsequent nucleophilic attack of **6** onto **8** affords aminal **10**; the resulting *N*-bromo-*p*-toluenesulfonamide (**9**) may serve as a Brønsted acid to promote the addition. Finally, intramolecular cyclization of **10** leads to the formation of the diaziridine product **3**. The key to the success of this diaziridination is the use of an NBS/base oxidation system that permits the generation of sufficient amounts of bromamine salt **6** and bromoamine **7**, resulting in the smooth formation of the fused diaziridine **3**.



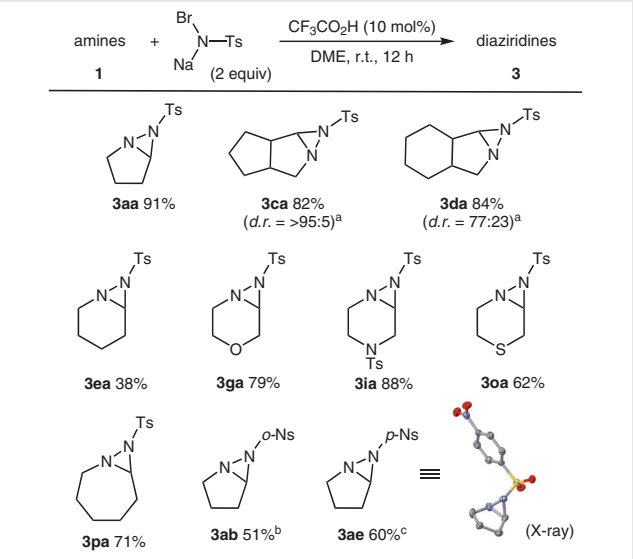
Scheme 8 Plausible mechanism

We assumed that in situ generated *N*-bromo-*p*-toluenesulfonamide (**9**) would function not only as a Brønsted acid but also as a brominating reagent instead of NBS. To examine this possibility, the reaction of **1a** with bromamine-T in the presence of CF_3CO_2H, which enables the protonation of bromamine-T to generate **9**, was examined (Scheme 9).[11] When 100 mol% of CF_3CO_2H was used, diaziridine **3aa** was formed in 32% yield. As compound **9** is regenerated during the formation of the imine from **7** with bromamine-T, based on the proposed reaction pathway described in Scheme 8, a catalytic amount of CF_3CO_2H would be sufficient to allow the diaziridination to proceed. In fact, addition of 10 mol% of CF_3CO_2H is sufficient to promote the diaziridination, providing **3aa** in 91% yield.



Scheme 9 Reaction of pyrrolidine (**1a**) with bromamine-T in the presence of CF_3CO_2H

We then investigated the substrate scope for this acid-catalyzed diaziridination (Scheme 10). The method was successfully applied to the preparation of a series of cyclic secondary amines including five-, six-, and seven-membered ring systems. Thiomorpholine was not a suitable substrate in the NBS/base system (not shown in this report) but could be used as a reactant in the acid-catalyzed diaziridination (**3oa**). Notably, product yields were generally higher than those from the NBS/base oxidation system. Moreover, not only bromamine-T but also bromamine-*o*-Ns and bromamine-*p*-Ns could be used in this acid-catalyzed method, affording **3ab** and **3ae**, respectively.[12]



Scheme 10 Substrate scope for the acid-catalyzed method. *Reagents and conditions*: **1** (0.5 mmol), NaNBrTs (2 equiv), CF_3CO_2H (10 mol%), DME (5 mL), r.t., 12 h. [a] Determined by ^1H NMR analysis of the crude product. [b] Bromamine-*o*-Ns was used instead of bromamine-T. [c] Bromamine-*p*-Ns was used instead of bromamine-T.

In conclusion, new and practical methods for the synthesis of fused diaziridine derivatives from cyclic secondary amines were developed. The NBS/base oxidation system was successfully applied to the reaction of cyclic secondary amines with *p*-toluenesulfonamide, in which *N*-bromoamines (and cyclic imines) and bromamine salts are efficiently produced. In addition, a valid and reliable alternative method using bromamine-T as an aminating reagent in the presence of a catalytic amount of CF_3CO_2H was also achieved.

New compounds were characterized by ^1H, ^{13}C, and ^{19}F NMR spectroscopy, IR spectroscopy, MS, and HRMS. ^1H, ^{13}C, and ^{19}F NMR spectra were recorded on a JEOL JMTC-400/54/SS spectrometer (^1H NMR, 400 MHz; ^{13}C NMR, 100 MHz; ^{19}F NMR, 377 MHz). ^1H NMR chemical shifts were determined relative to Me_4Si (0.0 ppm) as an internal standard in $CDCl_3$ or residual undeuterated methanol (3.31 ppm) in CD_3OD.

^{13}C NMR chemical shifts were determined relative to $CDCl_3$ (77.0 ppm) and CD_3OD (49.0 ppm). ^{19}F NMR chemical shifts were determined relative to C_6F_6 (–164.9 ppm in $CDCl_3$) as an external standard. Infrared spectra were recorded on a SHIMADZU IRAffinity-1 FT-IR spectrophotometer. Mass spectra were obtained on a SHIMADZU GCMS-QP2010 mass spectrometer. High-resolution mass spectra were obtained on JEOL JMS-700 (magnetic sector type mass spectrometer) and JEOL JMS-T100LP mass spectrometers. Melting points were determined on a Stanford Research Systems MPA100 OptiMelt Automated Melting Point System. The X-ray diffraction data of the single crystal were collected on a two-dimensional X-ray detector (PILATUS 200K/R) attached to a Rigaku XtaLAB PRO diffractometer by using thin multi-layer mirror monochromated Cu-Kα radiation (λ =1.54187 Å). All reactions were carried out under nitrogen. Products were purified by chromatography on silica gel BW-300 or Chromatorex NH (Fuji Silysia Chemical Ltd.). Analytical thin-layer chromatography (TLC) was performed on pre-coated silica gel glass plates (Merck silica gel 60 F_{254} and Fuji Silysia Chromatorex NH, 0.25 mm thickness). Compounds were visualized under a UV lamp or by treatment with an ethanolic solution of phosphomolybdic acid followed by heating. Recycle gel permeation chromatography (GPC) was performed with $CHCl_3$ as the eluent.

Cyclic secondary amines methyl pyrrolidine-2-carboxylate hydrochloride (**1b**),[13] 2-phenylpyrrolidine,[14] and 1-tosylpiperazine (**1i**),[15] were prepared according to reported procedures. 1-Pyrroline was prepared according to a reported procedure.[7d] *N*-Bromo-*N*-sodio-*p*-toluenesulfonamide (bromamine-T), *N*-bromo-*N*-sodio-2-nitrobenzenesulfonamide (bromamine-*o*-Ns), and *N*-bromo-*N*-sodio-4-nitrobenzenesulfonamide (bromamine-*p*-Ns) were prepared according to a reported procedure.[8b,9] All other solvents and reagents were purchased and used as obtained.

1-((2-Nitrophenyl)sulfonyl)piperazine (1j)

According to the reported procedure,[16] the reaction was carried out by using piperazine (864.5 mg, 10.0 mmol), CH_2Cl_2 (60 mL), triethylamine (1.66 g, 16.4 mmol), and 2-nitrobenzenesulfonylchloride (3.32 g, 15.0 mmol). Purification by washing with water (3 × 10 mL) to remove trimethylamine hydrochloride gave the product as a pale-yellow solid (1.02 g, 38% yield); mp 142.2–143.2 °C.

IR (ATR): 3088, 2963, 2837, 1587, 1557, 1439, 1375, 1356, 1325, 1234, 1165, 1130, 1076, 1043, 947, 878, 853, 791, 764, 748, 733 cm^{-1}.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.95 (d, *J* = 8.0 Hz, 1 H), 7.76–7.67 (m, 2 H), 7.46 (d, *J* = 8.0 Hz, 1 H), 3.26 (t, *J* = 5.6 Hz, 4 H), 2.93 (t, *J* = 5.6 Hz, 4 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ = 148.3, 133.7, 131.4, 130.8, 130.6, 123.9, 46.7, 45.4.

HRMS (FAB+): *m*/*z* [M + H]$^+$ calcd for $C_{10}H_{14}N_3O_4S$: 272.0705; found: 272.0706.

N-Bromo-*N*-potassio-*p*-toluenesulfonamide (6)

According to the reported procedure,[8b,9] the reaction was carried out by using chloramine-T·3 H_2O (8.4 g, 29.9 mmol), H_2O (150 ml), bromine (1.93 mL, 37.5 mmol), and aq. KOH (5 M, 150 mL). Purification by recrystallization from water gave the product as a pale-yellow solid (2.24 g, 24% yield), which was determined by elemental analysis to be TsNBrK·1.5 H_2O.

IR (ATR): 3441, 3375, 3248, 3034, 3022, 1645, 1597, 1493, 1393, 1373, 1304, 1209, 1121, 1088, 1018, 947, 810, 706 cm^{-1}.

^{1}H NMR (CD_3OD, 400 MHz): δ = 7.72 (d, *J* = 8.4 Hz, 1 H), 7.26 (d, *J* = 8.4 Hz, 1 H), 2.39 (s, 3 H).

^{13}C NMR (CD_3OD, 100 MHz): δ = 142.3, 141.3, 129.7, 128.6, 21.3.

Anal. Calcd for $C_7H_{10}BrKNO_{3.5}S$: C, 26.67; H, 3.20; N, 4.44. Found: C, 26.46; H, 2.93; N, 4.39.

Diaziridination with $TsNH_2$ in the NBS/Base Oxidation System; General Procedure GP1

A reaction flask containing a magnetic stirrer bar was charged with $TsNH_2$ (0.5 mmol), NBS (0.5 mmol), K_2CO_3 (0.5 mmol), and MeCN (5 mL). To the mixture, an amine (0.5 mmol) was added, and the mixture was stirred at room temperature for 3 h on the benchtop. The reaction was quenched by addition of aq. $Na_2S_2O_3$ (1 M, 5 mL) and extracted with EtOAc (3 × 10 mL). The collected organic layers were dried over Na_2SO_4. The solution was concentrated under reduced pressure to give the crude product, which was analyzed by ^{1}H NMR spectroscopy with 1,1,2,2-tetrachloroethane as an internal standard. Purification by flash column chromatography on silica gel (hexane/EtOAc) or GPC ($CHCl_3$, JAIGEL-2H) gave the product.

Diaziridination with Bromamine-T; General Procedure GP2

A reaction flask containing a magnetic stirrer bar was charged with bromamine-T·3 H_2O (1 mmol), 1,2-dimethoxyethane (5 mL), and CF_3CO_2H (0.05 mmol). To the mixture, an amine (0.5 mmol) was added, and the mixture was stirred at room temperature for 12 h. The reaction was quenched by addition of aq. $Na_2S_2O_3$ (1 M, 10 mL) and extracted with CH_2Cl_2 (3 × 20 mL). The collected organic layers were dried over Na_2SO_4. The solution was concentrated under reduced pressure to give the crude product, which was analyzed by ^{1}H NMR spectroscopy with 1,1,2,2-tetrachloroethane as an internal standard. Purification by flash column chromatography on silica gel (hexane/EtOAc) gave the product.

6-Tosyl-1,6-diazabicyclo[3.1.0]hexane (3aa)

GP1; white solid; yield: 105.7 mg (88%); mp 90.8–92.0 °C.

GP2; yield: 108.2 mg (91%).

TLC: R_f = 0.10 (hexane/EtOAc, 8:2).

IR (ATR): 3032, 2986, 2956, 2863, 1597, 1447, 1335, 1159, 1119, 1091, 1080, 980 cm^{-1}.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.85 (d, *J* = 8.4 Hz, 2 H), 7.35 (d, *J* = 8.4 Hz, 2 H), 4.09 (d, *J* = 2.8 Hz, 1 H), 3.17–3.11 (m, 1 H), 2.81–2.73 (m, 1 H), 2.46 (s, 3 H), 2.41–2.35 (m, 1 H), 1.91–1.81 (m, 1 H), 1.61–1.55 (m, 2 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ = 144.9, 133.0, 129.5, 129.0, 66.3, 54.2, 26.6, 21.7, 19.4.

HRMS (CI): *m*/*z* [M + H]$^+$ calcd for $C_{11}H_{15}N_2O_2S$: 239.0854; found: 239.0855.

Methyl 6-Tosyl-1,6-diazabicyclo[3.1.0]hexane-5-carboxylate (3ba)

GP1; yellow oil; yield: 65.1 mg (44%).

TLC: R_f = 0.15 (hexane/EtOAc, 1:1).

IR (ATR): 2955, 1748, 1597, 1439, 1366, 1339, 1290, 1244, 1223, 1186, 1163, 1111, 1086, 1016, 976, 937, 910, 874, 820, 775, 735 cm^{-1}.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.89 (d, *J* = 8.4 Hz, 2 H), 7.35 (d, *J* = 8.4 Hz, 2 H), 3.91 (s, 3 H), 3.09–2.99 (m, 2 H), 2.69–2.63 (m, 1 H), 2.46 (s, 3 H), 2.09–2.01 (m, 1 H), 1.72–1.66 (m, 2 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ = 166.1, 145.1, 134.2, 129.5, 128.8, 77.2, 55.5, 53.2, 30.7, 21.7, 20.1.

HRMS (FAB+): *m*/*z* [M + H]$^+$ calcd for $C_{13}H_{17}N_2O_4S$: 297.0909; found: 297.0914.

1-Tosyloctahydrocyclopenta[*c*]diazirino[1,3-*a*]pyrrole (3ca)

GP1; major isomer as a white solid; yield: 70.9 mg (51%); mp 113.5–114.0 °C; minor isomer as a white solid; yield: 12.9 mg (9%); mp 91.5–92.0 °C.

GP2; major isomer; yield: 114.6 mg (82%).

Major isomer:

TLC: R_f = 0.38 (hexane/EtOAc, 7:3).

IR (ATR): 2945, 2936, 2926, 1595, 1331, 1294, 1172, 1152, 1117, 1090, 1011, 955, 853, 843, 810, 756cm^{-1}.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.84 (d, *J* = 8.4 Hz, 2 H), 7.35 (d, *J* = 8.4 Hz, 2 H), 4.01 (s, 1 H), 3.25 (dd, *J* =13.2, 8.0 Hz, 1 H), 3.06–3.00 (m, 1 H), 2.56–2.49 (m, 2 H), 2.46 (s, 3 H), 1.83–1.74 (m, 1 H), 1.66–1.54 (m, 4 H), 1.38–1.35 (m, 1 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ = 144.9, 133.1, 129.5, 128.8, 71.3, 61.8, 46.1, 41.4, 31.4, 28.3, 25.0, 21.7.

HRMS (FAB+): *m*/*z* [M + H]$^+$ calcd for $C_{14}H_{19}N_2O_2S$: 279.1167; found: 279.1167.

Minor isomer:

TLC: R_f = 0.25 (hexane/EtOAc, 7:3).

IR (ATR): 2956, 2936, 2920, 2866, 1709, 1595, 1443, 1341, 1304, 1186, 1121, 1086, 1061, 993, 953, 862, 816, 785 cm^{-1}.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.83 (d, *J* = 8.4 Hz, 2 H), 7.35 (d, *J* = 8.4 Hz, 2 H), 4.04 (d, *J* = 4.0 Hz, 1 H), 3.19 (dd, *J* = 14.4, 8.8 Hz, 1 H), 2.96 (dd, *J* = 14.0, 2.4 Hz, 1 H), 2.92–2.86 (m, 1 H), 2.60–2.55 (m, 1 H), 2.46 (s, 3 H), 1.94–1.78 (m, 3 H), 1.72–1.67 (m, 1 H), 1.54–1.48 (m, 1 H), 1.40–1.34 (m, 1 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ = 144.8, 133.1, 129.5, 128.8, 71.5, 60.6, 45.4, 45.2, 33.9, 28.5, 27.7, 21.7.

HRMS (FAB+): *m*/*z* [M + H]$^+$ calcd for $C_{14}H_{19}N_2O_2S$: 279.1167; found: 279.1166.

1-Tosyloctahydro-1*H*-diazirino[3,1-*a*]isoindole (3da)

GP1; major isomer as a white solid; yield: 62.6 mg (42%); mp 100.5–111.5 °C; minor isomer as a white solid; yield: 36.6 mg (25%); mp 100.5–101.0 °C.

GP2; combined yield of stereoisomers: 122.6 mg (84%).

Major isomer:

TLC: R_f = 0.25 (hexane/EtOAc, 7:3).

IR (ATR): 2945, 2920, 2857, 1597, 1439, 1339, 1321, 1240, 1207, 1186, 1159, 1086, 1020, 980, 907, 870, 837, 802, 752 cm^{-1}.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.84 (d, *J* = 8.8 Hz, 2 H), 7.35 (d, *J* = 8.8 Hz, 2 H), 3.96 (d, *J* = 2.8 Hz, 1 H), 3.07 (dd, 13.6, 7.6 Hz, 1 H) 2.91 (d, *J* = 13.6 Hz, 1 H) 2.46 (s, 3 H), 2.45–2.42 (m, 1 H), 2.05–2.00 (m, 1 H), 1.93–1.89 (m, 1 H), 1.74–1.60 (m, 2 H), 1.57–1.45 (m, 2 H), 1.44–1.37 (m, 2 H), 1.11–1.06 (m, 1 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ = 144.8, 133.3, 129.5, 128.7, 70.0, 61.1, 37.4, 33.0, 30.6, 24.5, 23.2, 21.7, 21.3.

HRMS (FAB+): *m*/*z* [M + H]$^+$ calcd for $C_{15}H_{21}N_2O_2S$: 293.1324; found: 293.1323.

Minor isomer:

TLC: R_f = 0.38 (hexane/EtOAc, 7:3).

IR (ATR): 2920, 2856, 1726, 1595, 1449, 1331, 1292, 1258, 1089, 986, 962, 910, 893, 841, 810, 785 cm^{-1}.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.84 (d, *J* = 8.4 Hz, 2 H), 7.35 (d, *J* = 8.4 Hz, 2 H), 3.90 (s, 1 H), 2.97 (dd, *J* = 13.2, 8.4 Hz, 1 H) 2.71 (dd, *J* = 13.2, 11.2 Hz, 1 H) 2.46 (s, 3 H), 2.43–2.39 (m, 1 H), 2.22–2.17 (m, 1 H), 1.80–1.71 (m, 1 H), 1.70–1.62 (m, 1 H), 1.52–1.49 (m, 3 H), 1.25–0.96 (m, 3 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ = 144.8, 133.2, 129.5, 128.8, 69.8, 55.1, 37.2, 30.1, 25.0, 24.1, 22.5, 21.7, 20.9.

HRMS (FAB+): *m*/*z* [M + H]$^+$ calcd for $C_{15}H_{21}N_2O_2S$: 293.1324; found: 293.1328.

7-Tosyl-1,7-diazabicyclo[4.1.0]heptane (3ea)

GP1; yellow solid; yield: 63.3 mg (50%); mp 110.5–112.0 °C.

GP2; yield: 48.4 mg (38%).

TLC: R_f = 0.30 (hexane/EtOAc, 7:3).

IR (ATR): 2943, 2864, 1927, 1811, 1726, 1597, 1445, 1335, 1304, 1163, 1086, 970, 922, 812, 725 cm^{-1}.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.83 (d, *J* = 8.4 Hz, 2 H), 7.35 (d, *J* = 8.4 Hz, 2 H), 3.76 (d, *J* = 4.8 Hz, 1 H), 3.17–3.10 (m, 1 H), 2.94–2.88 (m, 1 H), 2.46 (s, 3 H), 2.24–2.17 (m, 1 H), 2.04–1.96 (m, 1 H), 1.55–1.46 (m, 2 H), 1.36–1.21 (m, 2 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ = 144.8, 132.4, 129.4, 128.9, 58.4, 49.0, 21.9, 21.6, 19.5, 16.3.

HRMS (FAB+): *m*/*z* [M + H]$^+$ calcd for $C_{12}H_{17}N_2O_2S$: 253.1011; found: 253.1014.

Ethyl 7-Tosyl-1,7-diazabicyclo[4.1.0]heptane-4-carboxylate (3fa)

GP1; major isomer as a yellow oil; yield: 48.2 mg (30%); minor isomer as a yellow oil; yield: 49.1 mg (30%).

Major isomer:

TLC: R_f = 0.30 (hexane/EtOAc, 1:1).

IR (ATR): 2982, 2967, 2938, 1726, 1713, 1597, 1445, 1381, 1331, 1306, 1256, 1184, 1159, 1090, 1030, 941, 908, 812, 727 cm^{-1}.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.82 (d, *J* = 8.4 Hz, 2 H), 7.36 (d, *J* = 8.4 Hz, 2 H), 4.12 (q, *J* = 7.4 Hz, 2 H), 3.83 (d, *J* = 5.6 Hz, 1 H), 3.16–3.11 (m, 1 H), 3.03–2.95 (m, 1 H), 2.46 (s, 3 H), 2.45–2.40 (m, 1 H), 2.35–2.27 (m, 2 H), 1.77–1.57 (m, 1 H), 1.57–1.53 (m, 1 H), 1.24 (t, *J* = 7.4 Hz, 3 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ = 173.4, 145.0, 132.3, 129.5, 128.9, 60.8, 57.3, 48.3, 34.5, 22.8, 21.7, 21.1, 14.1.

HRMS (FAB+): *m*/*z* [M + H]$^+$ calcd for $C_{15}H_{21}N_2O_4S$: 325.1222; found: 325.1221.

Minor isomer:

TLC: R_f = 0.40 (hexane/EtOAc, 1:1).

IR (ATR): 2980, 2959, 2938, 1728, 1597, 1447, 1381, 1325, 1250, 1184, 1159, 1088, 1032, 1018, 970, 814, 789, 756 cm^{-1}.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.82 (d, *J* = 8.0 Hz, 2 H), 7.36 (d, *J* = 8.0 Hz, 2 H), 4.12 (q, *J* = 7.2 Hz, 2 H), 3.86 (d, *J* = 3.6 Hz, 1 H), 3.37–3.31 (m, 1 H), 2.94–2.87 (m, 1 H), 2.61–2.45 (m, 2 H), 2.46 (s, 3 H), 2.18–2.11 (m, 1 H), 1.82–1.78 (m, 1 H), 1.50–1.40 (m, 1 H), 1.23 (t, *J* = 7.2 Hz, 3 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ = 173.8, 145.1, 132.1, 129.5, 129.0, 60.8, 58.9, 47.9, 33.4, 24.9, 23.1, 21.6, 14.0.

HRMS (FAB+): *m*/*z* [M + H]$^+$ calcd for $C_{15}H_{21}N_2O_4S$: 325.1222; found: 325.1217.

7-Tosyl-4-oxa-1,7-diazabicyclo[4.1.0]heptane (3ga)

GP1; white solid; yield: 78.4 mg (61%); mp 97.9–98.7 °C.

GP2; yield: 100.3 mg (79%).

TLC: R_f = 0.30 (hexane/EtOAc, 7:3).

IR (ATR): 2971, 2945, 2902, 2859, 1959, 1438, 1465, 1381, 1336, 1301, 1262, 1159, 1126, 1087, 1056, 1005, 926, 862, 779, 705 cm^{-1}.

^1H NMR ($CDCl_3$, 400 MHz): δ = 7.85 (d, *J* = 8.4 Hz, 2 H), 7.37 (d, *J* = 8.4 Hz, 2 H), 4.24 (d, *J* = 13.2 Hz, 1 H), 4.09 (dd, *J* = 13.2, 3.6 Hz, 1 H), 3.77 (d, *J* = 3.6 Hz, 1 H), 3.64–3.59 (m, 1 H), 3.35–3.29 (m, 1 H), 3.21–3.14 (m, 1 H), 2.96–2.90 (m, 1 H), 2.47 (s, 3 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ = 145.3, 132.1, 129.6, 129.1, 62.1, 60.7, 55.6, 47.8, 21.7.

HRMS (CI): *m*/*z* [M + H]$^+$ calcd for $C_{11}H_{15}N_2O_3S$: 255.0803; found: 255.0805.

***tert*-Butyl 7-Tosyl-1,4,7-triazabicyclo[4.1.0]heptane-4-carboxylate (3ha)**

GP1; white solid; yield: 80.2 mg (45%); mp 112.5–113.0 °C.

TLC: R_f = 0.25 (hexane/EtOAc, 7:3).

IR (ATR): 2976, 2968, 1693, 1597, 1412, 1391, 1364, 1331, 1292, 1184, 1159, 1112, 1090, 1007, 989, 897, 868, 833, 810, 772, 760 cm^{-1}.

^1H NMR ($CDCl_3$, 400 MHz): δ (mixture of rotamers) = 7.84 (d, *J* = 8.4 Hz, 2 H), 7.37 (d, *J* = 8.4 Hz, 2 H), 4.04 (dd, *J* = 15.2, 15.2 Hz, 1 H), 3.87–3.76 (m, 2 H), 3.30–3.26 (m, 2 H), 3.10–3.07 (m, 2 H), 2.47 (s, 3 H), 1.44 (s, 9 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ (observable signals in the mixture of rotamers) = 154.3, 145.3, 132.3, 132.0, 129.6, 128.9 80.5, 80.4, 57.2, 56.4, 48.0, 39.5, 38.2, 37.2, 36.2, 28.2, 21.7.

HRMS (FAB+): *m*/*z* [M + H]$^+$ calcd for $C_{16}H_{24}N_3O_4S$: 354.1488; found: 354.1491.

4,7-Ditosyl-1,4,7-triazabicyclo[4.1.0]heptane (3ia)

GP1; white solid; yield: 63.0 mg (31%); mp 122.1–123.8 °C.

GP2; yield: 180.2 mg (88%).

TLC: R_f = 0.18 (hexane/EtOAc, 7:3).

IR (ATR): 2952, 2859, 2362, 1922, 1596, 1493, 1457, 1345, 1306, 1214, 1183, 1163, 1111, 1088, 1019, 991, 974, 951, 736 cm^{-1}.

^1H NMR ($CDCl_3$, 400 MHz): δ = 7.75 (d, *J* = 8.4 Hz, 2 H), 7.60 (d, *J* = 8.4 Hz, 2 H), 7.34–7.27 (m, 4 H), 3.87–3.77 (m, 2 H), 3.49 (d, *J* = 13.2 Hz, 1 H), 3.23–3.19 (m, 1 H), 3.13–3.08 (m, 1 H), 2.99 (dt, *J* = 14.0, 4.0 Hz, 1 H), 2.85–2.79 (m, 1 H), 2.50–2.40 (m, 6 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ =145.5, 144.2, 132.6, 131.6, 129.9, 129.6, 129.1, 127.5, 55.8, 48.6, 40.9, 38.6, 21.7, 21.5.

HRMS (CI): *m*/*z* [M + H]$^+$ calcd for $C_{18}H_{22}N_3O_4S_2$: 408.1052; found: 408.1057.

4-((2-Nitrophenyl)sulfonyl)-7-tosyl-1,4,7-triazabicyclo[4.1.0]heptane (3ja)

GP1; white solid; yield: 192.8 mg (87%); mp 107.0–108.5 °C.

TLC: R_f = 0.30 (hexane/EtOAc, 1:1).

IR (ATR): 2926, 1595, 1541, 1439, 1337, 1271, 1159, 1126, 1090, 1059, 955, 887, 853, 812, 777, 727 cm^{-1}.

^1H NMR ($CDCl_3$, 400 MHz): δ = 7.98–7.94 (m, 1 H), 7.78–7.66 (m, 4 H), 7.64 (d, *J* = 8.0 Hz, 1 H), 7.35 (d, *J* = 8.0 Hz, 2 H), 3.96 (d, *J* = 2.8 Hz, 2 H), 3.89 (dd, *J* = 2.8, 2.8 Hz, 1 H), 3.30 (dd, *J* = 9.2, 4.4 Hz, 2 H), 3.24–3.17 (m, 1 H), 3.07 (dt, *J* = 14.0, 4.0 Hz, 1 H), 2.46 (s, 3 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ = 148.1, 145.6, 134.0, 131.9, 131.5, 131.2, 130.9, 129.7, 129.1, 124.4, 55.9, 48.1, 40.6, 38.9, 21.7.

HRMS (FAB+): *m*/*z* [M + H]$^+$ calcd for $C_{17}H_{19}N_4O_6S_2$: 439.0746; found: 439.0748.

1-Benzyl-3-phenyl-2-tosyldiaziridine (3ka)

GP1; colorless oil; yield: 42.6 mg (24%).

^1H NMR ($CDCl_3$, 400 MHz): δ = 7.71 (d, *J* = 8.0 Hz, 2 H), 7.53–7.50 (m, 2 H), 7.44–7.40 (m, 3 H), 7.16–7.12 (m, 3 H), 7.03 (t, *J* = 8.0 Hz, 2 H), 6.91 (d, *J* = 7.2 Hz, 2 H), 4.92 (s, 1 H), 3.35 (d, *J* = 13.2 Hz, 1 H), 3.28 (d, *J* = 13.2 Hz, 1 H), 2.41 (s, 3 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ = 144.9, 135.8, 131.8, 129.7, 129.34, 129.27, 129.15, 129.09, 129.06, 128.4, 128.1, 127.0, 63.3, 56.0, 21.7.

The analytical data for this compound were in excellent agreement with the reported data.[5e]

1-Butyl-3-propyl-2-tosyldiaziridine (3la)

GP1; yellow oil; yield: 35.1 mg (23%).

TLC: R_f = 0.30 (hexane/EtOAc, 9:1).

IR (ATR): 2959, 2932, 2874, 1597, 1495, 1458, 1402, 1335, 1257, 1119, 1090, 962, 876, 814, 760 cm^{-1}.

^1H NMR ($CDCl_3$, 400 MHz): δ = 7.84 (d, *J* = 8.4 Hz, 2 H), 7.35 (d, *J* = 8.4 Hz, 2 H), 3.62 (dd, *J* = 7.2, 4.8 Hz, 1 H), 2.62–2.55 (m, 1 H), 2.46 (s, 3 H), 2.41–2.35 (m, 1 H), 1.75–1.58 (m, 2 H), 1.58–1.49 (m, 2 H), 1.27–1.10 (m, 4 H), 1.00 (t, *J* = 7.2 Hz, 3 H), 0.77 (t, *J* = 7.2 Hz, 3 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ = 145.0, 132.4, 129.4, 128.4, 63.8, 51.8, 30.4, 27.2, 21.7, 20.2, 19.6, 13.8, 13.7.

HRMS (FAB+): *m*/*z* [M + H]$^+$ calcd for $C_{15}H_{25}N_2O_2S$: 297.1637; found: 297.1642.

1-Methyl-2-tosyl-3-(4-(trifluoromethyl)phenyl)diaziridine (3ma)

GP1; white solid; yield: 143.2 mg (83%); mp 82.5–83.5°C.

TLC: R_f = 0.38 (hexane/EtOAc, 1:1).

IR (ATR): 3078, 2980, 2932, 1620, 1595, 1452, 1422, 1337, 1263, 1161, 1136, 1105, 1088, 1065, 1005, 876, 843, 802, 764 cm^{-1}.

^1H NMR ($CDCl_3$, 400 MHz): δ = 7.92 (d, *J* = 8.4 Hz, 2 H), 7.66 (d, *J* = 7.6 Hz, 2 H), 7.57 (d, *J* = 7.6 Hz, 2 H), 7.40 (d, *J* = 8.4 Hz, 2 H), 4.76 (s, 1 H), 2.49 (s, 3 H), 2.17 (s, 3 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ = 145.5, 133.1, 132.0, 131.7 (q, *J* = 32.1 Hz), 129.7, 129.4, 129.1, 125.4 (q, *J* = 3.3 Hz), 123.6 (q, *J* = 270.9 Hz), 63.1, 38.9, 21.7.

^{19}F NMR ($CDCl_3$, 377 MHz): δ = −65.4.

HRMS (FAB+): *m*/*z* [M + H]$^+$ calcd for $C_{16}H_{16}F_3N_2O_2S$: 357.0885; found: 357.0886.

7-Tosyl-4-thia-1,7-diazabicyclo[4.1.0]heptane (3oa)

GP2; white solid; yield: 83.6 mg (62%); mp 78.3–79.9 °C.

TLC: R_f = 0.40 (hexane/EtOAc, 7:3)

IR (ATR): 2917, 2914, 2865, 1922, 1593, 1386, 1330, 1296, 1176, 1161, 1143, 1092, 1060, 988, 893, 758 cm^{-1}.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.83 (d, *J* = 8.4 Hz, 2 H), 7.37 (d, *J* = 8.4 Hz, 2 H), 3.96 (dd, *J* = 6.0, 3.2 Hz, 1 H), 3.34–3.27 (m, 1 H), 3.23 (dd, *J* = 14.4, 3.2 Hz, 1 H), 3.12–3.04 (m, 2 H), 2.77–2.71 (m, 1 H), 2.47 (s, 3 H), 2.32–2.25 (m, 1 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ = 145.3, 132.0, 129.6, 129.1, 55.8, 48.1, 21.9, 21.7, 21.3.

HRMS (CI): *m*/*z* [M + H]$^+$ calcd for $C_{11}H_{15}N_2O_2S_2$: 271.0575; found: 271.0574.

8-Tosyl-1,8-diazabicyclo[5.1.0]octane (3pa)

GP2; yellow oil; yield: 93.9 mg (71%).

TLC: R_f = 0.25 (hexane/EtOAc, 8:2).

IR (ATR): 2926, 2858, 1598, 1401, 1335, 1163, 1091, 1120, 1048, 1034, 934, 914, 866, 814, 732 cm^{-1}.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.85 (d, *J* = 8.4 Hz, 2 H), 7.35 (d, *J* = 8.4 Hz, 2 H), 3.80 (dd, *J* = 9.2, 4.4 Hz, 1 H), 3.18 (dd, *J* = 12.4, 7.2 Hz, 1 H), 2.52 (t, *J* = 11.2 Hz, 1 H), 2.46 (s, 3 H), 2.29–2.22 (m, 1 H), 1.83–1.65 (m, 4 H), 1.59–1.45 (m, 2 H), 1.23–1.21 (m, 1 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ =144.8, 133.2, 129.5, 128.8, 63.0, 54.1, 30.2, 27.0, 25.7, 24.6, 21.7.

HRMS (CI): *m*/*z* [M + H]$^+$ calcd for $C_{13}H_{19}N_2O_2S$: 267.1167; found: 267.1169.

6-((2-Nitrophenyl)sulfonyl)-1,6-diazabicyclo[3.1.0]hexane (3ab)

GP2; yellow oil; yield: 60.3 mg (51%).

TLC: R_f = 0.21 (hexane/EtOAc, 7:3).

IR (ATR): 3103, 3051, 2992, 2926, 2855, 1730, 1595, 1537, 1460, 1439, 1359, 1344, 1315, 1292, 1263, 1236, 1195, 1163, 1144, 1123, 1061, 1032, 964, 905, 873, 843, 773, 750, 732, 727, 700 cm^{-1}.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 8.25–8.15 (m, 1 H), 7.84–7.75 (m, 3 H), 4.37 (d, *J* = 3.2 Hz, 1 H), 3.38 (ddd, *J* = 14.0, 7.6, 2.8 Hz, 1 H), 2.93–2.85 (m, 1 H), 2.48 (ddd, *J* = 14.8, 6.8, 1.6 Hz, 1 H), 1.98–1.89 (m, 1 H), 1.69–1.55 (m, 2 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ = 148.9, 134.8, 132.3, 132.2, 132.0, 130.0, 124.4, 69.5, 54.8, 26.7, 19.1.

HRMS (CI): *m*/*z* [M + H]$^+$ calcd for $C_{10}H_{12}N_3O_4S$: 270.0549; found: 270.0548.

6-((4-Nitrophenyl)sulfonyl)-1,6-diazabicyclo[3.1.0]hexane (3ae)

GP2; yellow solid; yield: 80.1 mg (60%); mp 82.3–85.5 °C.

TLC: R_f = 0.23 (hexane/EtOAc, 7:3).

IR (ATR): 3115, 3111, 2973, 2952, 2944, 2879, 2873, 1609, 1559, 1524, 1402, 1350, 1337, 1316, 1308, 1300, 1289, 1178, 1173, 1106, 1091, 1086, 1012, 969, 910, 877, 857, 851, 830, 780, 755, 740, 732 cm^{-1}.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 8.41 (d, *J* = 8.8 Hz, 2 H), 8.18 (d, *J* = 8.8 Hz, 2 H), 4.25 (d, *J* = 2.8 Hz, 1 H), 3.09 (ddd, *J* = 13.2, 7.2, 1.6 Hz, 1 H), 2.83–2.75 (m, 1 H), 2.43 (ddd, *J* = 14.8, 8.0, 1.6 Hz, 1 H), 1.98–1.88 (m, 1 H), 1.64–1.54 (m, 2 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ = 150.8, 142.0, 130.3, 124.0, 67.3, 54.3, 26.6, 19.2.

HRMS (CI): *m*/*z* [M + H]$^+$ calcd for $C_{10}H_{12}N_3O_4S$: 270.0549; found: 270.0549.

4-Methyl-*N*-(5-phenyl-3,4-dihydro-2*H*-pyrrol-4-yl)benzenesulfonamide (4)

GP1; yellow solid; yield: 60.4 mg (39%); mp 146.5–147.3 °C.

TLC: R_f = 0.50 (hexane/EtOAc, 2:8).

IR (ATR): 3240, 2859, 1622, 1595, 1576, 1493, 1444, 1331, 1290, 1184, 1155, 1086, 1059, 1024, 972, 924, 899, 858, 814, 774 cm^{-1}.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.73 (d, *J* = 8.0 Hz, 2 H), 7.70 (d, *J* = 7.2 Hz, 2 H), 7.40 (t, *J* = 7.2 Hz, 1 H), 7.31 (d, *J* = 8.0 Hz, 2 H), 7.27 (d, *J* = 7.2 Hz, 2 H), 5.07 (br d, *J* = 8.8 Hz, 1 H), 4.96–4.89 (m, 1 H), 3.93–3.88 (m, 2 H), 2.46 (s, 3 H), 2.13–2.04 (m, 1 H), 1.67–1.59 (m, 1 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ = 170.3, 143.8, 137.4, 131.7, 130.7, 129.8, 128.5, 128.2, 127.2, 59.5, 58.9, 31.5, 21.6.

HRMS (FAB+): *m*/*z* [M + H]$^+$ calcd for $C_{17}H_{19}N_2O_2S$: 315.1167; found: 315.1174.

***tert*-Butyl 1,4,7-Triazabicyclo[4.1.0]heptane-4-carboxylate (5)**

According to the reported procedure,[5e] the reaction was carried out using *tert*-butyl-7-tosyl-1,4,7-triazabicyclo[4,1,0]heptane-4-carboxylate (**3ha**) (70.0 mg, 0.20 mmol), I_2 (5.2 mg, 0.02 mmol), Mg (50.2 mg, 2.1 mmol), and MeOH (3.0 mL). Purification by flash column chromatography on silica gel (hexane/EtOAc, 7:3) gave the product as a yellow solid (26.7 mg, 68%); mp 110.0–111.5 °C.

IR (ATR): 3240, 2976, 2932, 2870, 1670, 1545, 1456, 1427, 1391, 1364, 1288, 1244, 1163, 1120, 1103, 1061, 995, 979, 858, 826, 773, 756 735 cm^{-1}.

^{1}H NMR of mixture of rotamers ($CDCl_3$, 400 MHz): δ = 4.00–3.89 (m, 1 H), 3.75–3.66 (m, 1 H), 3.45–3.33 (m, 2 H), 3.23–3.25 (m, 3 H), 2.05 (d, *J* = 6.0 Hz, 1 H), 1.45 (s, 9 H).

Observable signals in the ^{13}C NMR of a mixture of rotamers ($CDCl_3$, 100 MHz): δ = 154.9, 154.7, 79.8, 50.3, 49.7, 48.4, 48.0, 39.9, 39.0, 37.7, 36.2, 28.4.

HRMS (FAB+): *m*/*z* [M + H]$^+$ calcd for $C_9H_{18}N_3O_2$: 200.1399; found: 200.1401.

Conflict of Interest

The authors declare no conflict of interest.

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Supporting Information

Supporting information for this article is available online at https://doi.org/10.1055/a-1468-8275.

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