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# Synthesis of Bridged Azabicycles from Pyridines and Pyrrole by a Diallylboration – Ring Closing Metathesis Sequence

Nikolai Yu. Kuznetsov,[a] Viktor N. Khrustalev,[a] Ivan A. Godovikov,[a] and Yuri N. Bubnov*[a]

**Keywords:** Alkenes / Allylic compounds / Boron / Allylic boranes / Allylboration / Nitrogen heterocycles / Cyclization / Metathesis / Synthetic methods

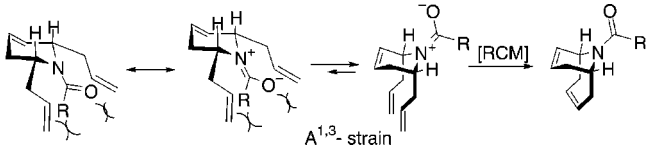
A straightforward method for the preparation of bridged azabicycles by a *diallylboration–ring closing metathesis* (RCM) sequence was elaborated. The precursors for the metathesis reaction were prepared by reductive *trans*-diallylation of aromatic heterocycles such as pyridines, isoquinoline and pyrrole with triallylborane and an alcohol. Heating of the *trans* isomers with one equivalent of triallylborane allowed the corresponding *cis* isomers – or (in the case of pyrrole) a mixture of *cis* and *trans* isomers – to be obtained. Boc protection of the amine function gave the precursor for the RCM reaction with axial orientations of allylic groups. The chemical yields of this stage are very good and the amounts of Grubbs' catalyst required for the reaction do not exceed 2.5 mol-% (first generation cat.) or 3.7 mol-% (second generation cat.). Azabicyclo[4.2.1]nonene, obtained from pyrrole, is a key structural motif of the toxin pinnamine. The structures of *cis*-1,3-diallyl-1,2,3,4-tetrahydroisoquinoline and azabicyclo[4.3.1]-decadiene were studied by single-crystal X-ray analysis.


## Introduction

Bridged azabicycles represent a unique class of compounds displaying a wide spectrum of biological activity.[1] The development of effective synthetic methods for the construction of bicyclic units has therefore attracted the attention of chemists for a long time.

Although the ring closing metathesis (RCM) reaction has now become quite usual in the synthesis of cyclic systems,[2] only a few papers, starting from the work of Neipp and Martin,[3a] have been concerned with the construction of bridged azabicycles by RCM.[3] Application of the RCM reaction has thus opened a quick route to the key structural subunit of indole alkaloids of the *sarpagine* and *ajmaline* families.[3c] Total syntheses of well known alkaloids such as (+)-anatoxin-a,[3d] (+)-ferruginine,[3e] and the new coccinellid alkaloid (–)-adaline[3b] have also been accomplished through RCM reactions. These examples clearly demonstrate serious potential for RCM reactions in the construction of bridged heterocyclic systems.

Generally, a major part of the synthetic work consists of the preparation of a substrate appropriate for RCM to be carried out. The key step of the synthesis is the introduction of unsaturated groups, in a *cis* arrangement, into the α and α′ positions in a heterocycle. There then follows the introduction of an acyl-type protecting group (Cbz, Boc, TFA), in order firstly to provide a biaxial conformation[4] of the reacting substituents (through $A^{1,3}$-strain),[3a] most favorable for RCM (Scheme 1), and secondly to suppress the base properties of the amine function, which would otherwise decrease the catalyst's efficacy.




Scheme 1.

We had previously found that pyridines,[5] isoquinoline,[6] and pyrrole[7] undergo reductive *trans*-α,α′-diallylation on treatment with allylic boranes (triallyl-, trimethallyl-, and tricrotylborane) and an alcohol to give the corresponding α,α-diallylated heterocyclic compounds. It was also found that *gem*-α,α-diallylation can be achieved on treatment of triallylborane with nitriles, carboxylic acids, esters,[8] lactams,[9a] and amides.[9b] It is noteworthy that compounds prepared by diallylboration are excellent candidates for RCM, and sequential allylboration of carbonyl compounds and metathesis has been shown to be a powerful tool in asymmetric syntheses of lactone-containing natural substances.[10] Recently, a simple method based on a tandem diallylboration-metathesis reaction for the synthesis of α-azaspirobicycles from cyclic lactams has also been elaborated.[11] Here we present a method that follows this strategy for the preparation of a number of azabicyclo[4.3.1]decadiene and azabicyclo[4.2.1]nonene structures.

[a] A. N. Nesmeyanov Institute of Organoelement Compounds, Russian Academy of Sciences,
Vavilov 28, 119991, Moscow, Russia
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Grubbs' catalysts of the first (**I**) and second generation (**II**) were used in the RCM reactions (Figure 1), owing to their stability and effectiveness.

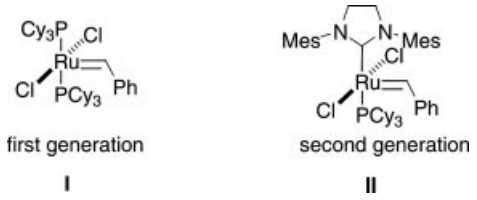



Figure 1. Grubbs' catalysts.

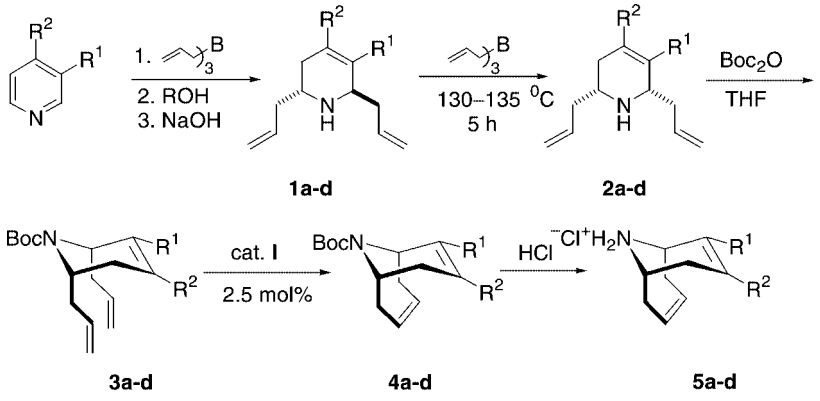
## Results and Discussion

A set of *trans*-diallylated heterocycles (**1a**–**f**) was prepared by reductive diallylation of several substituted pyridines (Scheme 2), quinoline (Scheme 3), and pyrrole (Scheme 3) with triallylborane in the presence of ROH (one-pot reaction).[5–7] The mechanism of the reaction between pyridine and triallylborane includes the formation of the corresponding complex, which exists in equilibrium with the monoallylated compound of dienamine-type structure. This intermediate is further protonated by the alcohol and undergoes the second intramolecular allylation step, giving the *trans*-α,α′-diallylated heterocycle.[5a,5f]

Heating of *trans* isomers **1a**–**d** with triallylborane (1:1) at 130–135 °C produces the corresponding *cis* isomers **2a**–**d** in high yields and purities (contamination with the *trans* isomers is in the 2–5% range). The mechanism of the isomerization includes a deprotonation stage (propylene evolution) and then a deallylation-allylation stage.[5] The deallylation stage is favored by allylic-type stabilization, due to the adjacent C=C bond.[5] In the case of **1e** (Scheme 3), the isomerization with triallylborane results in an equilibrium mixture of *cis* and *trans* isomers in a ratio close to 1:1.

Fortunately, the *cis* isomer **2e** was found to be a crystalline substance, separable from the liquid *trans* isomer **1e** in 85% yield by crystallization from hexane. Isomer **2e** can also be isolated by flash chromatography. The *cis* arrangement of the allylic groups at atoms C(1) and C(3) in compound **2e** was established by single-crystal X-ray analysis (Figure 2). The interesting structural feature of **2e** is a pincer-like arrangement of the allyl substituents, which tightly surround the hydrogen atom of the amino group. Such an arrangement is apparently determined by the bifurcate intramolecular N–H···$\pi_{C=C}$ hydrogen bond, with short H2···C10 and H2···C13 distances of 2.53(1) and 2.58(1) Å, respectively. Because of the disposition of the allyl groups, the nitrogen atom N2 has a reasonably pyramidal geometry with bond angles very close to the ideal tetrahedral value of 109.5° [C1–N2–C3 111.93(10), C1–N2–H2 107.9(10), and C3–N2–H2 109.8(11)°]; intermolecular hydrogen bonds in the structure **2e** are absent.

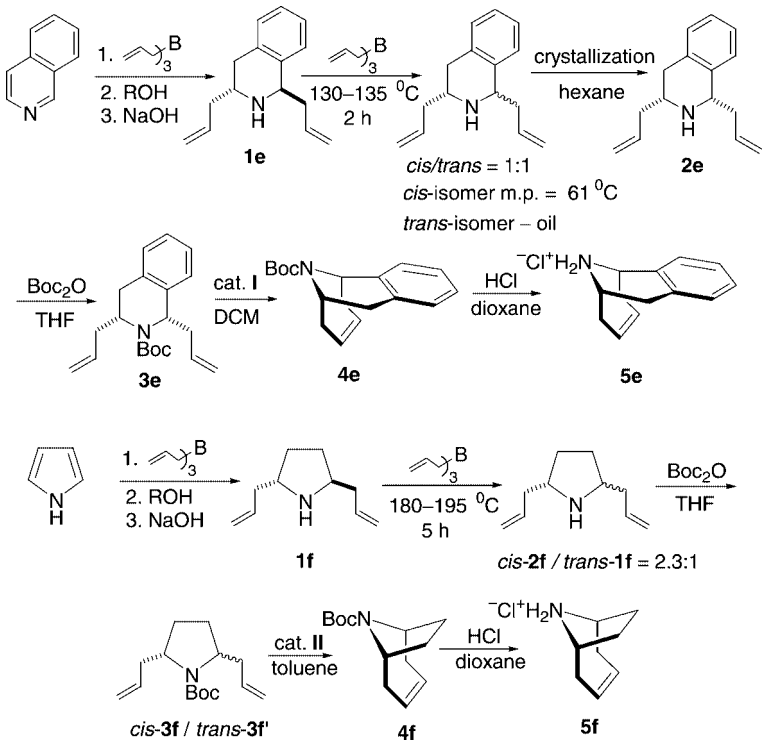
The isomerization of *trans*-2,5-diallylpyrrolidine proceeds under harder conditions than that of **1e** (due to the absence of allylic-type stabilization during the deallylation step),[7b] and provides a mixture of isomers (**1f/2f** = 1:2.3) after 5 hours heating with triallylborane at 185–195 °C. As in the case of **1e**, this is the equilibrium ratio of isomers, since it does not change upon prolonged heating. In this case we failed to separate the isomers, so the mixture of isomers was used in the next transformations. Amines **2a**–**e** and the **1f/2f** mixture were further treated with $Boc_2O$ in




| $R^1$ | $R^2$ | Compound number, Yield (%) | | | | |
|---|---|---|---|---|---|---|
| H- | H- | **1a**, 89% | **2a**, 94% | **3a**, 97% | **4a**, 95% | **5a**, 99% |
| H- | $CH_3$- | **1b**, 76% | **2b**, 95% | **3b**, 91% | **4b**, 98% | **5b**, 98% |
| H- | Br- | **1c**, 75% | **2c**, 92% | **3c**, 95% | **4c**, 89% | **5c**, 99% |
| Br- | H- | **1d**, 70% | **2d**, 93% | **3d**, 94% | **4d**, 91% | **5d**, 99% |
| isoquinoline | | **1e**, 95% | **2e**, 85% | **3e**, 98% | **4e**, 93% | **5e**, 99% |
| pyrrole | | **1f**, 56% | **2f**, 98% | **3f**, 98% | **4f**, 96% | **5f**, 99% |

Scheme 2.




Scheme 3.

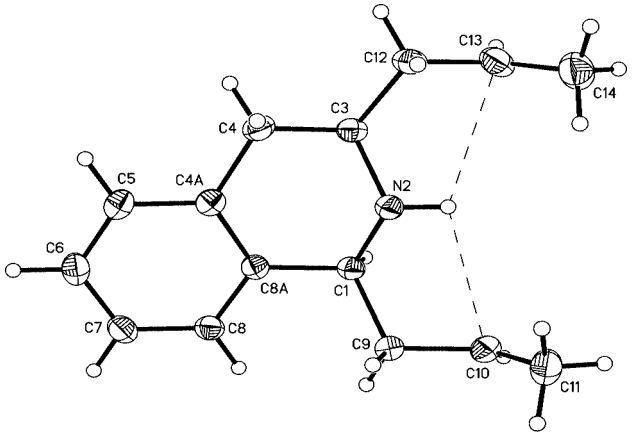



Figure 2. The molecule structure of *cis* isomer **2e** (50% probability ellipsoids).

THF, and *N*-Boc derivatives **3a**–**f** were applied in RCM reactions. The amount of catalyst **I** was in the 1.8 to 2.5 mol-% range, and the substrate concentrations for **3a**–**e** could be as high as 0.26 M. We did not observe the formation of any side products during RCM. The insignificant *trans* isomer impurities remained unchanged and were separated from the product by flash chromatography. The effective catalysis at a relatively high concentration is probably attributable to the optimal arrangement of allylic substituents in the reactant molecules. The Boc-protected bicycles were analyzed by NMR spectroscopy. Broadened and doubled signals were observed in the spectra, because of the hindered rotation around the C–N bonds in the amide fragments. This effect makes the NMR spectra of the protected bicycles poorly informative for the identification of the products.

The reaction with the pyrrolidine derivative **3f** especially attracted our attention because of the expected formation of the bicyclic 9-azabicyclo[4.2.1]nonane core, which has a structural similarity to the backbone of the marine toxin pinnamine[12] (Figure 3), the biological activity of which is insufficiently studied because of its scarcity.

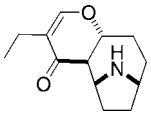


Figure 3. Marine toxin pinnamine.

The mixture of isomers **3f/3f′** was tested under RCM reaction with catalyst **I**, but the reaction did not take place either under standard conditions ($CH_2Cl_2$, 40 °C; 2.5–10 mol-% **I**) or under harsh conditions (toluene, 100 °C; 20 mol-% **I**). From the $^1H$ NMR spectra only 4% of the expected bicycle **4f** was detectable from the reaction at 100 °C. As it turned out, catalyst **I** probably does not work in such a pyrrolidine system (diene metathesis). However, the successful RCM conversion of *N*-Boc-*cis*-2-allyl-5-vinylpyrrolidine into a tropidine derivative had been achieved with the catalyst **II**.[3e] We took advantage of this finding and carried out a RCM reaction with the **3f/3f′** mixture and catalyst **II** (C = 0.015 M of **3f/3f′**, toluene, 80 °C). The bicycle **4f** was isolated by flash chromatography in 96% yield, calculated from the *cis* isomer **3f** content in the mixture. Interestingly, a uniform relationship was observed in the

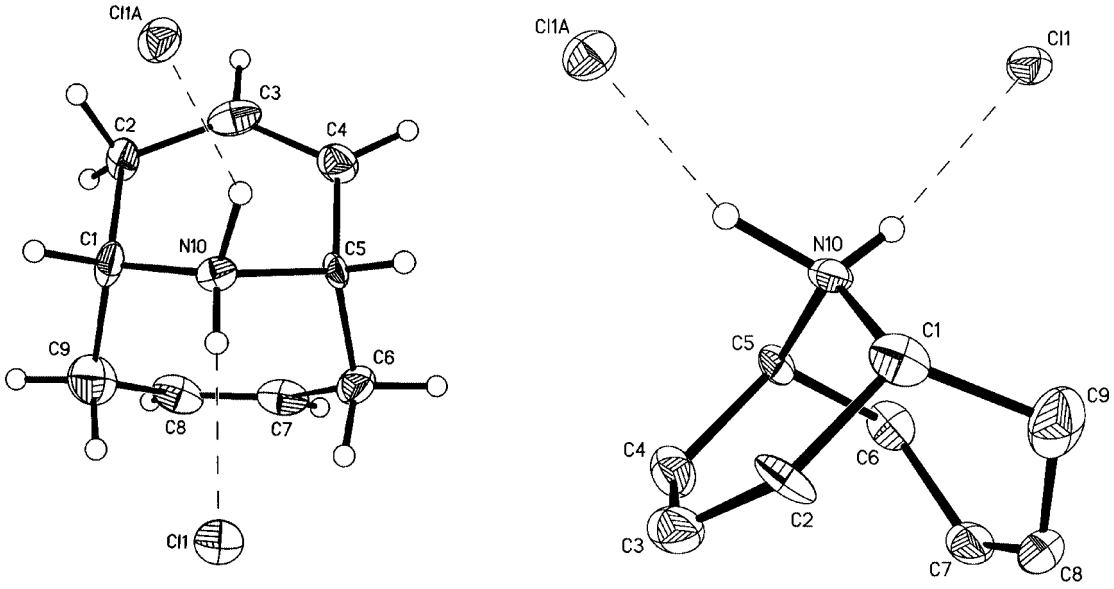



Figure 4. The structure of hydrochloride **5a** (50% probability ellipsoids).

cases of all compounds: a RCM product always had a lower $R_f$ than the initial compound on silica gel, which makes the separation and the identification of the products easier.

Deprotection of the Boc derivatives occurred readily upon heating (60–70 °C) with HCl solution (4 M) in dioxane; the chemical yields of the corresponding hydrochlorides **5a**–**f** were nearly quantitative. The structure of the bicycle **5a** (hydrochloride) was confirmed by single-crystal X-ray analysis (Figure 4). The six-membered ring in **5a** has a sofa conformation, and the seven-membered ring a chair conformation. The planar C1–C2–C3–C4–C5 fragment of the six-membered ring is unexpected, as the most favorable conformation of analogous cycles is a half-chair. The similar geometry of the 1,2,5,6-tetrahydropyridine fragments is characteristic, mainly, for bicyclic heterocycles.[13] In the crystal the cations and anions are bound through strong N–H···Cl hydrogen bonds (dotted lines in Figure 4) [N10–H10A···Cl1, N···Cl 3.153(2), H···Cl 2.28(3) Å, N–H···Cl 171(2)°] and N10–H10B···Cl1A [N···Cl 3.084(2), H···Cl 2.12(3) Å, N–H···Cl 167(2)°].

## Conclusions

The combination of reductive α,α′-diallylation of certain aromatic nitrogen heterocycles (pyridines, isoquinolines, pyrrole) and ring closing metathesis represents a simple and straightforward route to various azabicyclo[4.3.1]deca-3,7-dienes and azabicyclo[4.2.1]non-3-enes. Compounds **4c** and **4d**, as vinyl bromides, may be usable for further modification through palladium catalysis. We also hope that bicycle **4f** may be useful in the synthesis of the marine toxin pinnamine.

## Experimental Section

**General:** The procedures involving triallylborane were carried out under dry Ar. Triallylborane was prepared by the described method.[14] Compounds **1a**, **2a**, **1d**, **2d**,[5c] **1c**,[6] and **1f** and the **1f**/**2f** mixture[7] were prepared as described previously. NMR spectra were recorded on Bruker AMX 400, Avance 300, and WP-200SY instruments. Chemical shifts are given in $\delta$ (ppm) and $J$ values in Hz. Mass spectra were recorded on a Finnigan Polaris Q Ion Trap spectrometer. Column chromatography was carried out on silica gel (60–230 mesh, Merck).

***trans*-2,6-Diallyl-4-methyl-1,2,3,6-tetrahydropyridine (1b.):** Dry 4-picoline (20.5 g, 21.4 mL, 0.22 mol) was added dropwise at –30 °C to neat triallylborane (13.4 g, 16.8 mL, 0.1 mol) and the mixture was stirred for 10 min. When the temperature had reached 0 °C, propan-2-ol (24.0 g, 30.6 mL, 0.4 mol) was added in one portion and the mixture was heated at reflux for 2 hours and then treated with a solution of NaOH (5 N, 40 mL, 0.2 mol) with stirring. The organic layer was diluted with hexane, separated, and dried with $K_2CO_3$. Evaporation and vacuum distillation furnished **1b** (13.5 g, 76%) as a colorless liquid, which became red upon standing, b.p. 116–118 °C (18 Torr). $^1$H NMR (300 MHz, [D$_6$]DMSO): $\delta$ = 5.90–5.76 (m, 2 H), 5.38 (m, 1 H), 5.10–5.02 (m, 4 H), 3.27 (br. s, 1 H), 2.88 (dt, $J$ = 5.5, 7.3 Hz, 1 H), 2.17–2.09 (m, 4 H), 1.85 (dd, $J$ = 4.1, 17.1 Hz, 1 H), 1.70 (br. s, 2 H), 1.65 (s, 3 H) ppm. $^{13}$C NMR (75 MHz, [D$_6$]DMSO): $\delta$ = 136.97, 136.52, 132.07, 124.24, 116.97, 116.86, 51.80, 47.25, 40.35, 40.13, 36.33, 23.65 ppm.

***cis*-2,6-Diallyl-4-methyl-1,2,3,6-tetrahydropyridine (2b):** Triallylborane (4.4 g, 5.6 mL, 33 mmol) was added dropwise to **1b** (5.3 g, 29.8 mmol) with external cooling by water bath. When the propene evolution had ceased the mixture was heated at 130 °C for 5 hours. The reaction mixture was then treated successively with MeOH (5 ml) and NaOH (5 N, 20 mL, 0.1 mol). The upper organic layer was diluted with hexane (10 mL), separated, and dried with $K_2CO_3$, and the solvent was evaporated under reduced pressure. The residue was distilled in vacuo, which yielded **2b** (5.04 g, 95%) as a colorless liquid that became red upon standing; admixture with **1b** <5% according to $^1$H NMR spectroscopy. $^1$H NMR (400 MHz, [D$_6$]DMSO): $\delta$ = 5.81 (m, 1 H), 5.26 (s, 1 H), 5.07–5.00 (m, 4 H), 3.27 (br. s, 1 H), 2.69 (qt, $J$ = 4.0, 6.2, 6.5 Hz, 1 H), 2.11 (t, $J$ = 6.8 Hz, 2 H), 2.07 (t, $J$ = 6.6 Hz, 2 H), 1.75 (dt, $J$ = 3.1, 16.8 Hz, 1 H), 1.70 (br. d, $J$ = 10.3 Hz, 1 H), 1.60 (s, 3 H) ppm. $^{13}$C NMR (100 MHz, [D$_6$]DMSO): $\delta$ = 137.14 (CH), 137.00 (CH), 133.42 (C),

125.46 (CH), 117.86 (2×$CH_2$), 55.14 (CH), 53.55 (CH), 41.88 ($CH_2$), 41.85 ($CH_2$), 37.80 ($CH_2$), 24.16 ($CH_3$) ppm. MS (70 eV, EI): *m*/*z* 177 $[M]^+$ (3), 162 (5), 136 (100), 95 (20), 80 (25), 69 (23), 57 (66), 44 (27), 41 (51), 40 (65). $C_{12}H_{19}N$ (177.3): calcd. C 81.30, H 10.80, N 7.90; found C 81.16, 10.83, N 8.00.

***trans*-2,6-Diallyl-4-bromo-1,2,3,6-tetrahydropyridine (1c):** The procedure was the same as that used for **1b**. Yield: 75% as a colorless liquid, which became red upon standing, b.p. 93–94 °C (1 Torr). $^1$H NMR (400 MHz, $CDCl_3$): $\delta$ = 6.00 (s, 1 H), 5.76–5.65 (m, 2 H), 5.10–5.03 (m, 4 H), 3.41 (s, 1 H), 3.04 (m, 1 H), 2.40 (dd, *J* = 4.4, 17.1 Hz, 1 H), 2.28–2.17 (m, 4 H), 2.12 (m, 1 H), 1.91 (br. s, 1 H, NH) ppm. $^{13}$C NMR (75 MHz, $C_6D_6$): $\delta$ = 135.24, 134.90, 130.84, 120.21, 117.55, 117.38, 53.89, 48.69, 41.13, 39.51, 38.95 ppm. $C_{11}H_{16}BrN$ (242.2): calcd. C 54.56, H 6.66, N 5.78, Br 33.00; found C 54.48, H 6.67, N 5.71, Br 32.91.

***cis*-2,6-Diallyl-4-bromo-1,2,3,6-tetrahydropyridine (2c):** The procedure was the same as that used for **2b**. Yield: 92% as a colorless liquid, which became red upon standing. $^1$H NMR (400 MHz, $CDCl_3$): $\delta$ = 5.95 (s, 1 H), 5.79–5.68 (m, 2 H), 5.18–5.07 (m, 4 H), 3.42 (s, 1 H), 2.92 (m, 1 H), 2.37–2.12 (m, 6 H), 1.93 (br. s, 1 H, NH) ppm. $^{13}$C NMR (75 MHz, $C_6D_6$): $\delta$ = 134.47, 134.41, 131.16, 120.82, 117.84, 117.62, 56.05, 53.68, 41.75, 40.25, 40.01 ppm. MS (70 eV, EI): *m*/*z* 243 $[M]^+$ (0.6), 202 (46), 200 (55), 160 (96), 158 (100), 120 (87), 93 (33), 91 (44), 80 (76), 79 (57), 77 (50), 65 (27), 57 (23), 51 (36), 41 (69), 39 (69). $C_{11}H_{16}BrN$ (242.2): calcd. C 54.56, H 6.66, N 5.78, Br 33.00; found: C 54.51, H 6.69, N 5.73, Br 32.89.

***cis*-1,3-Diallyl-1,2,3,4-tetrahydroisoquinoline (2e):** *trans*-1,3-Diallyl-1,2,3,4-tetrahydroisoquinoline **1e**[6] (9.5 g, 46.8 mmol) and neat triallylborane (8.4 mL, 6.7 g, 50 mmol) were mixed with stirring at room temperature and the mixture was heated at 130–135 °C for 2 h. After being cooled the reaction mixture was quenched with MeOH (20 mL) and heated under reflux for 1 h. In order to complete deboronation, NaOH (5 N, 30 mL, 150 mmol) was added with stirring, and the organic layer was diluted with hexane (30 mL) and separated, dried with $K_2CO_3$, filtered, and concentrated under reduced pressure. According to $^1$H NMR the residue was a mixture of **1e** and **2e** in 1:1 ratio, yield of the mixture 9.1 g (96%) as a reddish oil. The mixture was subjected to flash chromatography on silica gel in hexane/AcOEt/$Et_3N$, 30:8:1; $R_f$(**1e**) = 0.38 and $R_f$(**2e**) = 0.5. Isomer **2e** was isolated as a white crystalline solid, yield 4.5 g (98%) calculated from the relative content in the mixture of isomers. It was also possible to separate **2e** by consecutive crystallizations of the mixture from chilled hexane, which gave **2e** in 85% total yield, m.p. 60–61 °C. $^1$H NMR (400 MHz, $CDCl_3$): $\delta$ = 7.22 (d, *J* = 6.8 Hz, 1 H), 7.17–7.11 (m, 2 H), 7.08 (d, *J* = 6.2 Hz, 1 H), 5.87–5.74 (m, 2 H), 5.24–5.12 (m, 4 H), 4.05 (d, *J* = 7.5 Hz, 1 H), 2.95–2.84 (m, 2 H), 2.73 (dd, *J* = 3.1, 15.9 Hz, 1 H), 2.62 (dd, *J* = 11.2, 15.8 Hz, 1 H), 2.49 (br. s, 1 H, NH), 2.45–2.23 (m, 3 H) ppm. $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 133.96, 131.46, 131.00, 130.83, 125.15, 122.10, 121.87, 120.93, 114.41, 113.79, 51.71, 48.44, 36.89, 36.02, 32.28 ppm. MS (70 eV, EI): *m*/*z* 213 $[M]^+$ (1), 212 (4), 172 (92), 131 (37), 130 (100), 129 (27), 116 (10), 115 (16), 91 (16), 77 (22), 58 (26), 41 (32), 39 (38). $C_{15}H_{19}N$ (213.3): calcd. C 84.46, H 8.98, N 6.57; found C 84.67, H 9.12, N 6.55.

***tert*-Butyl *cis*-2,6-Diallyl-4-methyl-1,2,3,6-tetrahydropyridine-1-carboxylate (3b):** Amine **2b** (4 g, 22.6 mmol) and $Boc_2O$ (5.2 g, 24 mmol) in THF (5 mL) solution were heated under reflux for 1 hour. The solvent was removed by evaporation and the residue was distilled in vacuo to give **3b** (5.7 g, 91%) as a colorless oil, b.p. 102–104 °C (0.1 Torr). $^1$H NMR (400 MHz, [$D_6$]DMSO): $\delta$ = 5.85–5.67 (m, 2 H), 5.39 (s, 1 H), 5.08–4.98 (m, 4 H), 4.36 (br. s, 1 H), 4.10 (br. s, 1 H), 2.39 (br. s, 1 H), 2.16 (m, 4 H), 1.83 (d, *J* = 17.1 Hz, 1 H), 1.67 (s, 3 H), 1.40 (s, 9 H) ppm. $^{13}$C NMR (100 MHz, [$D_6$]DMSO): $\delta$ = 154.79 (C=O), 137.28 (CH), 136.81 (CH), 130.32 (C), 120.45 (CH), 118.05 ($CH_2$), 117.89 ($CH_2$), 79.82 (C–O), 52.12 (br.), 48.12 (br.), 42.17 (br.), 39.92, 33.25 (br.), 29.18 (3×$CH_3$), 24.54 ppm. MS (70 eV, EI): *m*/*z* 277 $[M]^+$ (0.2), 236 (10), 196 (21), 180 (54), 152 (20), 136 (35), 94 (52), 69 (87), 57 (100), 55 (22), 41 (70), 39 (35). $C_{17}H_{27}NO_2$ (277.4): calcd. C 73.61, H 9.81, N 5.05; found: C 73.47, H 9.76, N 5.11.

***tert*-Butyl *cis*-2,6-Diallyl-1,2,3,6-tetrahydropyridine-1-carboxylate (3a):** Yield: 97%, as a colorless oil, b.p. 96–97 °C (0.1 Torr) $^1$H NMR (400 MHz, [$D_6$]DMSO): $\delta$ = 5.79–5.71 (m, 1 H), 5.70–5.67 (m, 3 H), 5.09–4.99 (m, 4 H), 4.36 (br. 1 H), 4.13 (br. 1 H), 2.41 (br. 1 H), 2.20–2.10 (br. 4 H), 2.00 (dd, *J* = 4.9, 17.1 Hz, 1 H), 1.40 (s, 9 H) ppm. $^{13}$C NMR (100 MHz, [$D_6$]DMSO): $\delta$ = 153.29, 135.97, 135.37, 125.68, 121.67, 116.96, 116.65, 78.66, 50.93 (br.), 45.98 (br.), 40.40 (br.), 38.52, 27.93, 27.93, 27.14 (br.) ppm. MS (70 eV, EI): *m*/*z* 263 $[M]^+$ (1), 222 (16), 167 (28), 166 (80), 122 (73), 85 (46), 80 (73), 71 (60), 69 (41), 57 (100), 55 (36), 41 (61). $C_{16}H_{25}NO_2$ (263.4): calcd. C 72.96, H 9.57, N 5.32; found C 72.94, H 9.62, N 5.08.

***tert*-Butyl *cis*-2,6-Diallyl-4-bromo-1,2,3,6-tetrahydropyridine-1-carboxylate (3c):** Yield: 95%, as a colorless oil, b.p. 122–123 °C (0.1 Torr). $^1$H NMR (300 MHz, $C_6D_6$): $\delta$ = 6.09 (s, 1 H), 5.82–5.68 (m, 2 H), 5.12–5.03 (m, 4 H), 4.63–4.22 (br. m, 2 H), 2.61–2.48 (br. m, 2 H), 2.34–2.26 (m, 2 H), 2.19–2.08 (m, 2 H), 1.53 (s, 9 H) ppm. $^{13}$C NMR (75 MHz, $C_6D_6$): $\delta$ = 153.73, 135.43, 134.74, 126.91, 117.47, 117.19, 79.31, 53.80, 49.28 (br.), 40.59 (br.), 39.02, 37.46, 28.12 (3×$CH_3$) ppm. MS (70 eV, EI): *m*/*z* 342 $[M]^+$ (0.6), 246 (20), 244 (21), 202 (39), 200 (42), 160 (38), 158 (38), 120 (42), 91 (45), 82 (58), 80 (55), 79 (43), 77 (42), 57 (100), 56 (28), 51 (40), 41 (90), 39 (77). $C_{16}H_{24}BrNO_2$ (342.3): calcd. C 56.15, H 7.07, N 4.09, Br 23.35; found: C 56.11, H 7.12, N 4.05, Br 23.30.

***tert*-Butyl *cis*-2,6-Diallyl-5-bromo-1,2,3,6-tetrahydropyridine-1-carboxylate (3d):** Yield: 94%, as colorless oil, b.p. 138–139 °C (0.2 Torr). $^1$H NMR (400 MHz, $CDCl_3$): $\delta$ = 6.06 (m, 1 H), 5.91 (dq, *J* = 7.8, 16.8 Hz, 1 H), 5.79–5.69 (m, 1 H), 5.09–5.01 (m, 4 H), 4.63–4.51 (br. m, 2 H), 2.86 (m, 1 H), 2.41–2.25 (m, 4 H), 2.11 (dd, *J* = 5.9, 17.4 Hz, 1 H), 1.45 (s, 9 H) ppm. $^{13}$C NMR (75 MHz, $C_6D_6$): $\delta$ = 154.10, 135.73, 133.57, 127.17, 122.09, 117.86, 116.87, 79.43, 59.26, 50.57, 38.36, 36.27, 28.88, 28.14 (3 $CH_3$) ppm. $C_{16}H_{24}BrNO_2$ (342.3): calcd. C 56.15, H 7.07, N 4.09, Br 23.35; found: C 56.14, H 7.09, N 4.00, Br 23.28.

***tert*-Butyl *cis*-1,3-Diallyl-1,2,3,4-tetrahydroisoquinoline-1-carboxylate (3e):** Yield: 98%, as a yellow oil. $R_f$ = 0.77 (hexane/AcOEt, 4:1). $^1$H NMR (400 MHz, $CDCl_3$): $\delta$ = 7.16 (s, 3 H), 7.11 (m, 1 H), 5.94–5.79 (br. m, 2 H), 5.26–5.05 (br. m, 4 H), 5.27 and 4.90 (br. signal, total 1 H), 4.37 and 4.05 (br. signal, total 1 H), 2.96 (dd, *J* = 6.8, 15.6 Hz, 1 H), 2.80 (dd, *J* = 7.8, 15.8 Hz, 1 H), 2.64 (br. s, 1 H), 2.59–2.48 (br. m, 2 H), 2.32–2.25 (m, 1 H), 1.48 (s, 9 H) ppm. $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 154.98, 135.54 (br.), 134.90, 132.93 (br.), 128.26/127.92 (br. d), 126.70, 126.26 (br.), 125.89, 117.09, 116.65, 79.67, 54.94, 51.00/49.43 (br. d), 42.49/41.79 (br. d), 41.37 (br.), 39.68 (br.), 32.14 (br.), 28.19 (3×$CH_3$) ppm. MS (70 eV, EI): *m*/*z* 313 $[M]^+$ (0.5), 272 (12), 216 (80), 172 (80), 130 (92), 115 (25), 83 (46), 77 (28), 69 (55), 57 (100), 56 (41), 41 (81), 39 (47). $C_{20}H_{27}NO_2$ (313.4): calcd. C 76.64, H 8.68, N 4.47; found C 76.69, H 8.59, N 4.51.

***tert*-Butyl 2,5-Diallylpyrrolidine-1-carboxylate (mixture of *cis* and *trans* isomers, 2.3:1) (3f):** The isomerization of *trans*-2,5-diallylpyrrolidine was carried out at 185–190 °C over 5 hours.[7b] The reaction with $Boc_2O$ was conducted as described for **3b**. Yield: 98%, as a colorless oil, b.p. 105–108 °C (0.5 Torr). $^1$H NMR (400 MHz,

$CDCl_3$): $\delta$ = 5.79–5.68 (m, 2 H), 5.07–5.01 (m, 4 H), 3.75–3.62 (br. m, 2 H), 2.52–2.33 (br. m, 2 H), 2.13–2.02 (br. m, 2 H), 1.91–1.80 (m, 2 H), 1.62 (m, 2 H), 1.41$_{trans}$ and 1.40 *cis* (2 s, 9 H total) ppm. $^{13}$C NMR (75 MHz, $C_6D_6$): $\delta$ = 154.10/153.09, 135.78/135.62, 135.54, 116.68/116.62, 116.53, 78.28/78.22, 58.02, 57.30/57.21, 40.22/39.56 (br.), 38.71/37.17, 28.28 (3×$CH_3$), 27.08/26.01 ppm. MS (70 eV, EI): *m*/*z* 252 [*M*]$^+$ (0.2), 210 (32), 155 (27), 154 (87), 111 (39), 110 (99), 68 (64), 67 (61), 57 (100), 56 (27), 41 (79), 39 (96). $C_{15}H_{25}NO_2$ (251.4): calcd. C 71.67, H 10.02, N 5.57; found C 71.69, H 10.09, N 5.55.

***tert*-Butyl 7,8-Benzo-10-azabicyclo[4.3.1]deca-3,7-diene-10-carboxylate (4e):** Catalyst **I** (0.14 g, 2.5 mol-%, 0.175 mmol) was added in two equal portions (each over 2 hours) to a degassed solution of **3e** (2.2 g, 7.0 mmol) in $CH_2Cl_2$ (50 mL). The reaction mixture was heated under reflux for 6 hours. After solvent removal the residue was subjected to flash chromatography on silica gel (hexane/AcOEt, 11:1) $R_f$(**4e**) = 0.34, $R_f$(**3e**) = 0.43, which furnished **4e** (1.86 g, 93%) as a colorless oil. *Signals in the NMR spectra are doubled and broadened because of hindered amide group rotation*. MS (70 eV, EI): *m*/*z* 285 [*M*]$^+$ (13), 229 (43), 184 (26), 175 (62), 174 (95), 131 (57), 130 (100), 115 (30), 103 (35), 77 (35), 57 (60), 41 (45), 39 (28). $C_{18}H_{23}NO_2$ (285.4): calcd. C 75.76, H 8.12, N 4.91; found C 75.73, H 8.14, N 4.77.

***tert*-Butyl 10-Azabicyclo[4.3.1]deca-3,7-diene-10-carboxylate (4a):** A mixture of **3a** (2 g, 7.6 mmol), catalyst **I** (110 mg, 1.8 mol-%), and $CH_2Cl_2$ (50 mL) was heated under reflux for 4 h. Flash chromatography was performed on silica gel (hexane/AcOEt, 7:1) $R_f$(**4a**) = 0.42; $R_f$(**3a**) = 0.63. Yield: (1.75 g, 98%), as colorless oil. *Signals in the NMR spectra are doubled and broadened because of hindered amide group rotation*. MS (70 eV, EI): *m*/*z* 235 [*M*]$^+$ (0.3), 180 (22), 179 (68), 162 (42), 125 (64), 124 (100), 91 (27), 80 (90), 79 (37), 57 (90), 56 (20), 41 (65), 39 (40). $C_{14}H_{21}NO_2$ (235.3): calcd. C 71.46, H 8.99, N 5.95; found C 71.45, H 8.96, N 5.97.

***tert*-Butyl 8-Methyl-10-azabicyclo[4.3.1]deca-3,7-diene-10-carboxylate (4b):** A mixture of **3b** (3.22 g, 11.6 mmol), catalyst **I** (180 mg, 1.8 mol-%), and $CH_2Cl_2$ (50 mL) was heated under reflux for 4 h. Flash chromatography was performed on silica gel (hexane/EtOAc, 9:1) $R_f$(**4b**) = 0.58, $R_f$(**3b**) = 0.73. Yield: (2.84 g, 98.2%) as a colorless oil. MS (70 eV, EI): *m*/*z* 249 [*M*]$^+$ (2), 149 (10), 125 (23), 111 (43), 97 (64), 95 (60), 85 (64), 83 (70), 71 (81), 69 (81), 57 (100), 56 (58), 41 (80), 39 (35). $C_{15}H_{23}NO_2$ (249.3): calcd. C 72.25, H 9.30, N 5.62; found: C 72.27, H 9.23, N 5.58.

***tert*-Butyl 8-Bromo-10-azabicyclo[4.3.1]deca-3,7-diene-10-carboxylate (4c):** A mixture of **3c** (2.08 g, 6 mmol), catalyst **I** (120 mg, 2.5 mol-%, 0.15 mmol), and $CH_2Cl_2$ (50 mL) was heated under reflux for 6 h. Flash chromatography was performed on silica gel (hexane/AcOEt, 11:1) $R_f$(**4c**) = 0.30. Yield: (1.68 g, 89%), as a colorless oil. MS (70 eV, EI): *m*/*z* 314 [*M*]$^+$ (0.1), 212 (10), 210 (10), 186 (22), 178 (36), 158 (30), 148 (20), 79 (30), 57 (100), 56 (72), 44 (83), 41 (80), 39 (62). $C_{14}H_{20}BrNO_2$ (314.2): calcd. C 53.51, H 6.42, N 4.46, Br 25.43; found C 53.52, H 6.35, N 4.46, Br 25.23.

***tert*-Butyl 7-Bromo-10-azabicyclo[4.3.1]deca-3,7-diene-10-carboxylate (4d):** A mixture of **3d** (2.08 g, 6 mmol) and catalyst **I** (120 mg, 2.5 mol-%, 0.15 mmol) in $CH_2Cl_2$ (50 mL) was heated under reflux for 6 h. Flash chromatography was performed on silica gel (hexane/AcOEt, 12:1) $R_f$(**4d**) = 0.39. Yield: (1.73 g, 91%), as a colorless oil. *Signals in the NMR spectra are doubled and broadened because of hindered amide group rotation*. $C_{14}H_{20}BrNO_2$ (314.2): calcd. C 53.51, H 6.42, N 4.46, Br 25.43; found C 53.55, H 6.39, N 4.44, Br 25.35.

***tert*-Butyl 9-Azabicyclo[4.2.1]non-3-ene-10-carboxylate (4f):** Catalyst **II** (100 mg, 3.7 mol-%, 0.11 mmol) was added in two portions (each over 2 hours) at 80 °C to a degassed solution of **3f** (0.75 g, 3.0 mmol) in toluene (200 mL). The reaction mixture was heated for 4 hours in total. The solvent was removed on a rotavap and flash chromatography of the residue with hexane/AcOEt, 12:1 [$R_f$(**4f**) = 0.21] furnished bicycle **4f** (0.44 g, 96%, cal. from the *cis* isomer content), as a colorless liquid. *Signals in the NMR spectra are doubled and broadened because of hindered amide group rotation*. $^1$H NMR (400 MHz, $CDCl_3$): $\delta$ = 5.48 (s, 2 H), 4.32 (br. s, 1 H), 4.21 (br. s, 1 H), 2.65 (d, *J* = 17.4 Hz, 1 H), 2.52 (d, *J* = 17.4 Hz, 1 H), 2.08 (d, *J* = 16.2 Hz, 2 H), 2.01 (m, 2 H), 1.62–1.53 (m, 2 H), 1.42 (s, 9 H) ppm. $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 153.68 C, 127.54 (CH), 126.76 (CH), 79.47 C, 55.52 ($CH_2$), 55.10 ($CH_2$), 37.69 ($CH_2$), 36.95 ($CH_2$), 30.30 ($CH_2$), 29.68 ($CH_2$), 29.20 (3×$CH_3$) ppm. MS (70 eV, EI): *m*/*z* 223 [*M*]$^+$ (19), 195 (47), 167 (71), 150 (71), 149 (69), 126 (68), 123 (54), 113 (70), 82 (70), 80 (60), 69 (90), 68 (80), 57 (100), 56 (57), 43 (41), 39 (64). $C_{13}H_{21}NO_2$ (223.3): calcd. C 69.92, H 9.48, N 6.27; found C 70.07, H 9.60, N 6.18.

**10-Azabicyclo[4.3.1]deca-3,7-diene Hydrochloride (5a):** The bicycle **4a** (0.47 g, 2 mmol) was dissolved directly in a dioxane solution of HCl (4 M, 2 mL, 8 mmol) and the mixture was heated at 60 °C for 10 min. $Et_2O$ (2 mL) was then added at room temperature, and precipitated crystals were filtered off and dried in air, to give **5a** (0.34 g, 99%) as a white powder, m.p. >260 °C (dec.). $^1$H NMR (400 MHz, [$D_6$]DMSO): $\delta$ = 9.79 (br. s, 1 H), 9.66 (br. s, 1 H), 5.85 (dt, *J* = 3.2, 10.5 Hz, 1 H), 5.79 (qt, *J* = 3.2, 8.6, 11 Hz, 1 H), 5.55–5.48 (m, 2 H), 4.05 (s, 1 H), 3.69 (m, 1 H), 2.83 (dquint, *J* = 2.7, 16.6 Hz, 1 H), 2.74 (dquint, *J* = 3.2, 16.4 Hz, 1 H), 2.55–2.47 (m, 1 H), 2.43 (ddd, *J* = 4.4, 8.6, 16.6 Hz, 1 H), 2.37 (ddd, *J* = 4.4, 8.6, 16.4 Hz, 1 H), 1.93 (ddd, *J* = 1.5, 4.4, 19.0 Hz, 1 H) ppm. $^{13}$C NMR (100 MHz, [$D_6$]DMSO): $\delta$ = 134.76, 134.06, 132.03, 128.57, 52.33, 50.29, 37.83, 32.21 ppm. MS (70 eV, EI): *m*/*z* 171 [*M*]$^+$ (0.5), 135 (28), 134 (11), 81 (70), 80 (100), 53 (18), 41 (12), 39 (16), 36 (28). $C_9H_{14}ClN$ (171.6): calcd. C 62.97, H 8.22, N 8.16, Cl 20.65; found C 62.93, H 8.17, N 8.21, Cl 20.58.

**8-Methyl-10-azabicyclo[4.3.1]deca-3,7-diene Hydrochloride (5b):** The bicycle **4b** (1.9 g, 7.6 mmol) was deprotected with a solution of HCl (4 M, 7.5 mL, 30 mmol) as described above, to give **5b** (1.38 g, 98%) as a white powder, m.p. 208–209 °C (dec.). $^1$H NMR (400 MHz, [$D_6$]DMSO): $\delta$ = 9.95 (s, 1 H), 9.66 (s, 1 H), 5.73 (t, *J* = 9.0 Hz, 1 H), 5.49 (t, *J* = 8.4 Hz, 1 H), 5.22 (s, 1 H), 3.99 (s, 1 H), 3.69 (s, 1 H), 2.79 (m, 2 H), 2.40 (m, 3 H), 1.79 (d, *J* = 18.4 Hz, 1 H), 1.62 (s, 3 H) ppm. $^{13}$C NMR (100 MHz, [$D_6$]DMSO): $\delta$ = 133.51, 129.20, 128.04, 117.33, 46.81, 44.84, 32.10, 30.98, 30.39, 22.77 ppm. MS (70 eV, EI): *m*/*z* 185 [*M*]$^+$ (0.8), 172 (6), 150 (12), 149 (35), 95 (74), 94 (100), 80 (59), 67 (30), 53 (36), 41 (50), 39 (52), 36 (56). $C_{10}H_{16}ClN$ (185.7): calcd. C 64.68, H 8.68, N 7.54, Cl 19.09; found: C 64.71, H 8.76, N 7.51, Cl 19.01.

**8-Bromo-10-azabicyclo[4.3.1]deca-3,7-diene Hydrochloride (5c):** The bicycle **4c** (1 g, 3.1 mmol) was deprotected with a solution of HCl (4 M, 2 mL, 8 mmol) as described above, to give **5c** (0.77 g, 99%) as a white powder, m.p. 271–273 °C (dec.). $^1$H NMR (400 MHz, [$D_6$]DMSO): $\delta$ = 10.27 (br. s, 1 H), 10.05 (br. s, 1 H), 5.97 (d, *J* = 4.7 Hz, 1 H), 5.82 (m, 1 H), 5.57 (m, 1 H), 4.17 (s, 1 H), 3.76 (m, 1 H), 2.93–2.74 (m, 3 H), 2.47 (ddd, *J* = 4.4, 8.7, 16.5 Hz, 1 H), 2.42 (ddd, *J* = 4.0, 8.4, 16.2 Hz, 1 H), 2.32 (d, *J* = 18.7 Hz, 1 H) ppm. $^{13}$C NMR (100 MHz, [$D_6$]DMSO): $\delta$ = 129.26, 128.42, 125.16, 119.99, 49.22, 46.42, 35.84, 31.62, 29.68 ppm. MS (70 eV, EI): *m*/*z* 250 [*M*]$^+$ (0.1), 216 (21), 172 (20), 160 (99), 158 (100), 134 (76), 80 (65), 79 (58), 51 (46), 41 (30), 39 (56). $C_9H_{13}BrClN$ (250.6): calcd. C 43.14, H 5.23, N 5.59; found C 43.15, H 5.21, N 5.60.

**7-Bromo-10-azabicyclo[4.3.1]deca-3,7-diene Hydrochloride (5d):** Yield **5d**: (0.77 g, 99%) as white powder, m.p. 193–197 °C (dec.). $^1$H NMR (300 MHz, [D$_6$]DMSO): $\delta$ = 10.43 (br. s, 1 H), 10.32 (br. s, 1 H), 6.29 (dd, $J$ = 3.0, 4.8 Hz, 1 H), 5.86 (m, 1 H), 5.62 (m, 1 H), 4.22 (s, 1 H), 3.76 (m, 1 H), 2.87 (ddt, $J$ = 3.0, 16.4, 25.3 Hz, 2 H), 2.69 (m, 1 H), 2.63 (dd, $J$ = 5.3, 8.2 Hz, 1 H), 2.42 (ddd, $J$ = 4.3, 8.7, 16.0 Hz, 1 H), 2.09 (dd, $J$ = 5.3, 18.9 Hz, 1 H) ppm. $^{13}$C NMR (75 MHz, [D$_6$]DMSO): hindered motion in the bicycle is observed in the spectrum, resulting in complication of most signals (see Supporting Information). Only small changes occur when the sample is heated up to 370 K. $C_9H_{13}BrClN$ (250.6): calcd. C 43.14, H 5.23, N 5.59; found: C 43.17, H 5.25, N 5.64.

**7,8-Benzo-10-azabicyclo[4.3.1]deca-3,7-diene Hydrochloride (5e):** The bicycle **4e** (1.05 g, 3.68 mmol) was dissolved directly in a dioxane solution of HCl (4 M, 4 mL, 16 mmol) and the mixture was heated at 70 °C for 30 min. Dilution of the resulting suspension with Et$_2$O (10 mL), and filtration yielded **5e** (0.81 g, 99%) as a white crystalline solid, m.p. >273 °C (dec.). $^1$H NMR (400 MHz, [D$_6$]DMSO): $\delta$ = 10.42 (d, $J$ = 8.7 Hz, 1 H), 10.10 (d, $J$ = 8.7 Hz, 1 H), 7.18–7.10 (m, 4 H), 5.68 (m, 1 H), 5.24 (m, 1 H), 4.77 (s, 1 H), 3.89 (s, 1 H), 3.27 (dd, $J$ = 8.4, 18.0 Hz, 1 H), 3.09 (d, $J$ = 16.2 Hz, 1 H), 2.89 (d, $J$ = 16.5 Hz, 1 H), 2.72 (d, $J$ = 18.0 Hz, 1 H), 2.67–2.59 (m, 1 H), 2.50–2.43 (m, 1 H) ppm. $^{13}$C NMR (100 MHz, [D$_6$]DMSO): $\delta$ = 132.3, 131.74, 129.01, 128.75, 127.97, 127.26, 125.96 (2×CH), 49.06, 44.92, 32.95, 31.63, 29.05 ppm. MS (70 eV, EI): $m/z$ 222 [$M$]$^+$ (0.1), 185 (36), 132 (36), 131 (68), 130 (100), 129 (56), 115 (28), 103 (42), 77 (42), 51 (28), 39 (27), 36 (42). $C_{13}H_{16}ClN$ (221.7): calcd. C 70.42, H 7.27, N 6.32, Cl 15.99; found C 70.57, H 7.36, N 6.25, Cl 16.01.

**9-Azabicyclo[4.2.1]non-3-ene Hydrochloride (5):** The bicycle **4f** (0.25 g, 1.1 mmol) was dissolved in HCl in dioxane (4 M, 3 mL, 12 mmol) and the mixture was heated at 70 °C for 10 min. The formed suspension was diluted with Et$_2$O (10 mL) and filtered to give **5f** (0.17 g, 99%) as white crystals, m.p. 234–235 °C. $^1$H NMR (400 MHz, [D$_6$]DMSO): $\delta$ = 9.69 (br. s, 2 H), 5.64 (s, 2 H), 4.04 (s, 2 H), 2.60 (d, $J$ = 17.1 Hz, 2 H), 2.36 (d, $J$ = 16.9 Hz, 2 H), 2.03 (m, 2 H), 1.60 (d, $J$ = 7.3 Hz, 2 H) ppm. $^{13}$C NMR (100 MHz, [D$_6$]-DMSO): $\delta$ = 127.1, 55.61 (t, $J$ = 33.7 Hz, C–N), 33.78, 28.35 ppm. MS (70 eV, EI): $m/z$ 159 [$M$]$^+$ (0.5), 123 (24), 94 (12), 82 (18), 80 (18), 69 (100), 68 (83), 44 (12), 43 (11), 36 (33). $C_8H_{14}ClN$ (159.6): calcd. C 60.18, H 8.84, N 8.77, Cl 22.21; found C 60.23, H 8.86, N 8.74, Cl 22.18.

**X-ray Structure Determination:** Data were collected on automated four-circle diffractometers: Siemens P3/PC (for **5a**) and Syntex P2$_1$ (for **2e**). For details see Table 1. The structures were solved by direct methods and by full-matrix, least-squares refinement with anisotropic thermal parameters for non-hydrogen atoms. The hydrogen atoms in the structure **2e** were located in difference Fourier syntheses and refined isotropically. The hydrogen atoms of amino group in the structure **5a** were located in difference Fourier syntheses and refined isotropically. The other hydrogen atoms in the structure **5a** were placed in calculated positions and refined in the riding model with fixed thermal parameters. The absolute structure of **1f** was determined by refinement of the Flack parameter, which was equal to 0.15(19). All calculations were carried out by use of the SHELXTL PLUS (PC Version 5.10) program.[15]

CCDC-275221 and -275220 (for **5a** and **2e**, respectively) contain 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.

Table 1. Crystallographic data for **2e** and **5a**.

| Compound | **2e** | **5a** |
|---|---|---|
| Empirical formula | $C_{15}H_{19}N$ | $C_9H_{14}ClN$ |
| Formula mass | 213.31 | 171.66 |
| Temperature [K] | 173(2) | 293(2) |
| Crystal size [mm] | 0.3×0.3×0.2 | 0.3×0.3×0.2 |
| Crystal system | monoclinic | monoclinic |
| Space group | $P2_1/c$ | $P2_1$ |
| $a$ [Å] | 10.499(2) | 6.6104(13) |
| $b$ [Å] | 13.516(3) | 7.2163(14) |
| $c$ [Å] | 9.795(2) | 9.6954(19) |
| α [°] | 90 | 90 |
| β [°] | 115.32(3) | 92.87(3) |
| γ [°] | 90 | 90 |
| $V$ [Å$^3$] | 1256.5(4) | 461.91(16) |
| $Z$ | 4 | 2 |
| $d_c$ [g cm$^{-3}$] | 1.128 | 1.234 |
| $F$(000) | 464 | 184 |
| $\mu$ [mm$^{-1}$] | 0.065 | 0.351 |
| θ range [°] | 2.62 to 27.06 | 3.09 to 28.06 |
| Index range | $-13 \le h \le 12$ | $0 \le h < = 8$ |
| | $-17 \le k \le 0$ | $0 \le k \le 9$ |
| | $0 \le l \le 12$ | $-12 \le l \le 12$ |
| No. of rflns. collected | 2872 | 1279 |
| No. of unique rflns. | 2711 | 1183 |
| No. of rflns. with $I > 2\sigma(I)$ | 2189 | 1131 |
| $R_1$; $wR_2$ [$I > 2\sigma(I)$] | 0.0476; 0.1210 | 0.0280; 0.0732 |
| $R_1$; $wR_2$ (all data) | 0.0610; 0.1310 | 0.0302; 0.0746 |
| Data/restraints/parameters | 2711/0/221 | 1183/1/109 |
| GOF on $F^2$ | 1.006 | 1.004 |
| Flack parameter | – | 0.15(19) |
| Max. shift/error | 0.001 | 0.001 |
| Largest diff. peak/hole [e Å$^{-3}$] | 0.262/–0.289 | 0.225/–0.137 |

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[1] a) G. A. Cordell, *Introduction to Alkaloids, A Biogenetic Approach*; Wiley-Interscience: New York, **1981**; b) M. Lounasmaa, T. Tamminen, in: *The Alkaloids, The Tropane Alkaloids*; Academic Press: New York, **1993**; vol. 44, 1–114.

[2] a) R. H. Grubbs, S. Chang, *Tetrahedron* **1998**, *54*, 4413–4450; b) A. Fürstner, *Angew. Chem. Int. Ed.* **2000**, *39*, 3012–3043; c) I. Nakamura, Y. Yamamoto, *Chem. Rev.* **2004**, *104*, 2127–2198; d) A. Deiters, S. F. Martin, *Chem. Rev.* **2004**, *104*, 2199–2238.

[3] a) C. E. Neipp, S. F. Martin, *Tetrahedron Lett.* **2002**, *43*, 1779–1782; b) T. Itoh, N. Yamazaki, C. Kibayashi, *Org. Lett.* **2002**, *4*, 2469–2472; c) C. E. Neipp, S. F. Martin, *J. Org. Chem.* **2003**, *68*, 8867–8878 and references cited therein; d) J. B. Brenneman, S. F. Martin, *Org. Lett.* **2004**, *6*, 1329–1331; e) V. K. Aggarwal, C. J. Astle, M. Rogers-Evans, *Org. Lett.* **2004**, *6*, 1469–1471.

[4] X-ray data confirming biaxial conformations of α,α′-substituents in several acyl piperidines: a) J. Quick, C. Mondello, M. Humora, T. Brennan, *J. Org. Chem.* **1978**, *43*, 2705–2708; b) Y. Mikata, *Acta Crystallogr., Sect. C: Cryst. Struct. Commun.* **1997**, *53*, 1486–1488.

[5] a) Yu. N. Bubnov, *Adv. Boron Chemistry* (Ed.: W. Siebert), **1997**, 123–138; b) Yu. N. Bubnov, *Russ. Chem. Bull.* **1995**, *44*, 1156–1170; c) Yu. N. Bubnov, E. A. Shagova, S. V. Evchenko, A. V. Ignatenko, *Russ. Chem. Bull.* **1994**, *43*, 645–656; d) Yu. N. Bubnov, E. A. Shagova, S. V. Evchenko, A. V. Ignatenko, I. D. Gridnev, *Bull. Acad. Sci. USSR Div. Chem. Sci. (Engl. Transl.)*

  

**1991**, *40*, 2315–2315; e) Yu. N. Bubnov, E. E. Demina, A. V. Ignatenko, *Russ. Chem. Bull.* **1997**, *46*, 627–629; f) Yu. N. Bubnov, E. E. Demina, A. V. Ignatenko, *Russ. Chem. Bull.* **1997**, *46*, 1361–1371.

[6] Yu. N. Bubnov, S. V. Evchenko, A. V. Ignatenko, *Russ. Chem. Bull.* **1993**, *42*, 1268–1269.

[7] a) Yu. N. Bubnov, L. I. Lavrinovich, A. Yu. Zikov, E. V. Klimkina, A. V. Ignatenko, *Russ. Chem. Bull.* **1993**, *42*, 1269–1270; b) Yu. N. Bubnov, E. V. Klimkina, L. I. Lavrinovich, A. Yu. Zikov, A. V. Ignatenko, *Russ. Chem. Bull.* **1999**, *48*, 1696–1705.

[8] a) B. M. Mikhailov, Yu. N. Bubnov, *Organoboron compounds in organic synthesis*; Harwood Acad. Sci. Publ., London, New York, **1984**; b) B. M. Mikhailov, Yu. N. Bubnov, A. V. Tsyban, M. Sh. Grigoryan, *J. Organomet. Chem.* **1978**, *154*, 131–145; c) Yu. N. Bubnov, M. A. Misharin, A. V. Ignatenko, *Tetrahedron Lett.* **1997**, *38*, 6259–6262.

[9] a) Yu. N. Bubnov, F. V. Pastukhov, I. V. Yampolsky, A. V. Ignatenko, *Eur. J. Org. Chem.* **2000**, 1503–1505; b) unpublished results.

[10] P. V. Ramachandran, M. V. R. Reddy, H. C. Brown, *Boron Chemistry at the Beginning of the 21st Century* (Ed.: Yu. N. Bubnov), Imeboron XI., **2002**, 66–77.

[11] P. Nieczypor, J. C. Mol, N. B. Bespalova, Yu. N. Bubnov, *Eur. J. Org. Chem.* **2004**, 812–819.

[12] a) H. Kigoshi, N. Hayashi, D. Uemura, *Tetrahedron Lett.* **2001**, *42*, 7469–7471; b) recent synthesis of pinnamine: T. Hjelmgaard, I. Søtofte, D. Tanner, *J. Org. Chem.* **2005**, *70*, 5688 –5697.

[13] a) L. Patient, M. B. Berry, S. J. Coles, M. B. Hursthouse, J. D. Kilburn, *J. Chem. Soc., Chem. Commun.* **2003**, 2552–2553; b) P. C. Meltzer, B. Wang, Z. Chen, P. Blundell, M. Jayaraman, M. D. Gonzalez, C. George, B. K. Madras, *J. Med. Chem.* **2001**, *44*, 2619–2635.

[14] L. I. Zakharkin, V. I. Stanko, *Izv. Acad. Nauk SSSR, Ser. Khim.* **1960**, 1896–1898; (*Chem. Abstr.* **1961**, *55*, 15337d).

[15] G. M. Sheldrick, SHELXTL, V 5.10, Bruker AXS Inc., Madison, WI, **1997**.

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