Synthesis F. Berti et al. Paper

Synthesis of 2,7-Diazabicyclo[2.2.1]heptenes by N–O Bond Cleavage of Arylnitroso Diels–Alder 1,2-Dihydropyridine Cycloadducts

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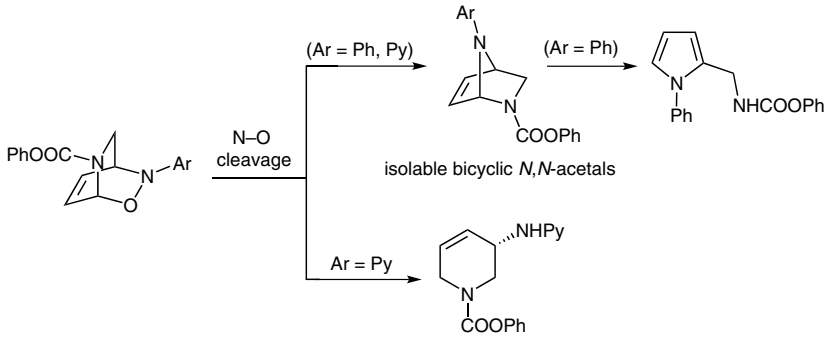

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Abstract The cleavage of the N–O bond of nitrosoarene-derived cycloadducts with 1,2-dihydropyridines gives different products depending on the protecting group of the starting dihydropyridine and reaction conditions. The use of catalytic amounts of CuCl in non-nucleophilic solvents in combination with a *N*-phenoxycarbonyl-protected nitrosophenyl-derived cycloadduct allowed the unprecedented formation of the 2,7-diazabicycle[2.2.1]heptene scaffold. It was also demonstrated that this novel bicyclic *gem*-diamine derivative is an isolable intermediate en route to pyrrole derivatives. On the other hand, the corresponding nitrosopyridine-derived cycloadduct showed to be unreactive with copper salts, but the application of different reductive conditions can deliver the corresponding bicyclic *gem*-diamine derivative or 3-aminotetrahydropyridine also in enantioenriched form.

Key words copper, Diels–Alder reaction, pyridines, rearrangement, pyrroles

Bridged diazabicycles are frequently found as structural motifs in biologically active alkaloids.[1] In particular, there are several diazabicyclic heptane derivatives [i.e., 2,5-diazabicyclo[2.2.1]heptanes (type I) and 3,6-diazabicyclo[3.1.1]heptanes (type II)] that possess a large variety of biological activities (Figure 1).[2] On the other hand, the preparation of the constrained 2,7-diazabicyclo[2.2.1]heptane scaffold (i.e., a bicyclic *gem*-diamine of type III) has not yet been described. Bicyclic *gem*-diamines are observed in natural products and biologically active compounds and various methods for their preparation have been reported.[3] We are aware of only one cyclization method to obtain five- and six-membered bicyclic *gem*-diamines involving the intermediacy of *N*-acyliminium ion.[4]

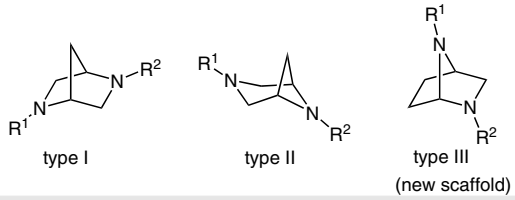
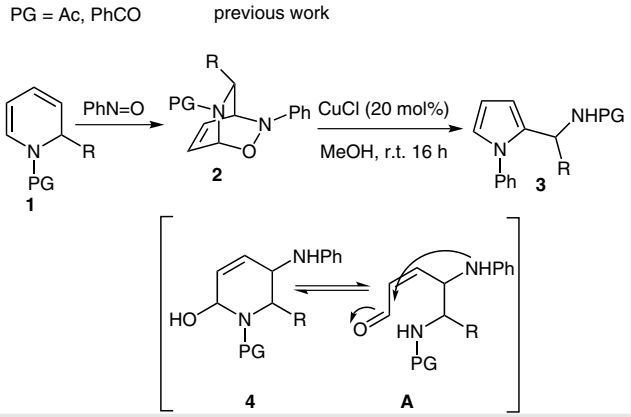


Figure 1 Basic structures of diazabicycloheptanes of type I–III

We recently found that the reductive cleavage of the N–O bond in nitrosobenzene-derived cycloadducts with 1,2-dihydropyridines allowed the formation of substituted pyrrole derivatives **3** (Scheme 1).[5] This transformation occurred effectively using catalytic amounts of CuCl (20 mol%) in MeOH only when the starting 1,2-dihydropyridine **1** was protected with particular protecting groups (PG = Ac, PhCO), whereas a carbamate protecting group such as Cbz proved to give a complex mixture of products.[5] In that work, we also speculated that such a process reasonably occurred through the intermediacy of an open chain amino aldehyde **A** followed by intramolecular cyclization, as depicted in Scheme 1. In fact, it is generally admitted that a cyclic hemiaminal such as **4**, obtained after the cleavage of the N–O bond, exists in equilibrium with open chain species **A**.[6] We hypothesized that only when the protecting group of the endocyclic piperidine nitrogen was sufficiently electron-withdrawing it was possible to shift the equilibrium to open-chain species **A** triggering the intramolecular cyclization to provide the corresponding pyrrole derivative.

We now report decisive evidences that *N*-acyliminium ions and 2,7-diazabicyclic[2.2.1]heptenes are the more plausible intermediates for the preparation of pyrrole derivatives. Moreover, we report that the new constrained bicyclic diamine scaffold can be selectively obtained, also in an enantioenriched form, by a careful choice of reaction conditions and protecting groups.

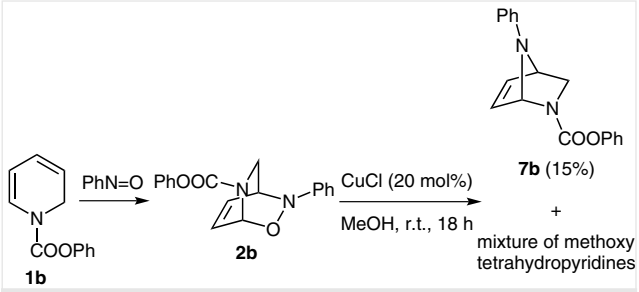


Scheme 1 Previous work with amide-protected 1,2-dihydropyridine and relative mechanistic hypothesis[5]

At the outset of this work, control experiments showed that when isolated hemiaminal **4a**, obtained by $TiCl_3$-mediated reduction of the corresponding phenylnitroso Diels–Alder cycloadduct,[5] was treated with catalytic amounts of CuCl in MeOH, methoxy 1,2,3,6-tetrahydropyridine **5a** was isolated as a single regio- and diastereoisomer.[7] Interestingly, in this reaction condition, which does not contemplate a reductive cleavage of the N–O bond, it was still possible to obtain the corresponding pyrrole derivative **3a**, albeit as a by-product (Scheme 2). These data suggested that conjugated *N*-acyliminium ion **6a** is a plausible key intermediate at least in the formation of methoxy tetrahydropyridine **5a**. As shown before for related compounds, steric repulsion between the methoxycarbonyl methyl group at C-2 position and the acetyl group on the nitrogen disfavors conformation **6aA** compared to **6aB** (Scheme 2).[8]

In accordance with previous observations obtained with imino glycals,[8b] the pseudoaxial attack of the methanol on **6aB** occurs on the seemingly more hindered face, to give compound **5a** with complete regio- and diastereoselectivity. However, at this point it was still possible that an open-chain mechanism via amino aldehyde present at equilibrium with hemiaminal **4a**, could be the cause of the formation of the minor product (i.e., the pyrrole derivative **3a**, via intermediate **A**, Scheme 1).

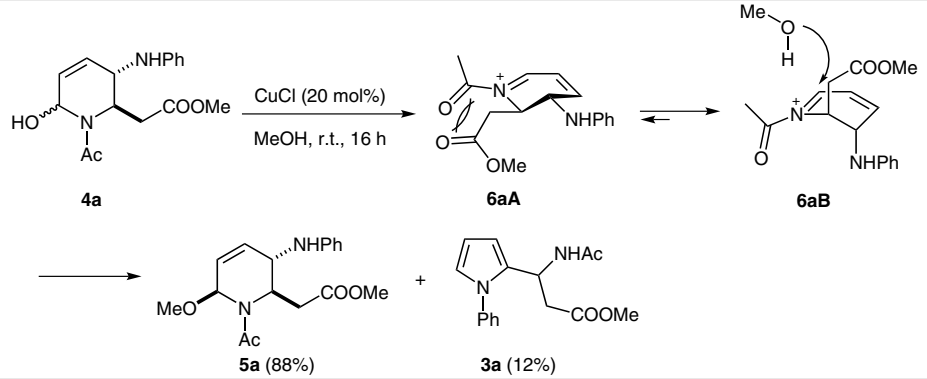
A further and decisive mechanistic insight was obtained using phenoxycarbonyl-protected cycloadduct **2b** (Scheme 3). The precursor, unsubstituted 1,2-dihydropyridine **1b**, is stable and easily available in multigram amounts by the application of a Fowler-type procedure.[9]



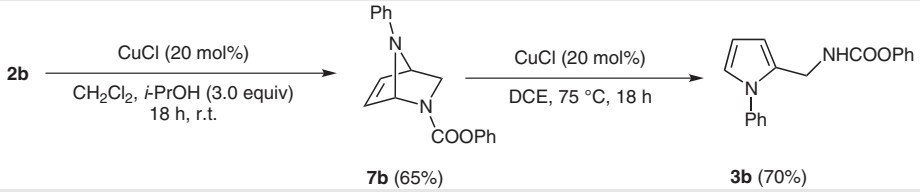
Scheme 3 Preliminary data indicating the formation of a 2,7-diazabicyclic heptene framework

When compound **2b** was treated with a catalytic amount of CuCl a complex mixture of products was obtained. As judged by ^{1}H NMR analysis, this mixture consisted of mainly regioisomeric methoxy tetrahydropyridines, which resulted as unseparable after chromatographic purification, without trace of the corresponding expected pyrrole derivative. It was curious that the novel bicyclic *gem*-*N*,*N*-acetal **7b** was isolated in 15% yield from this crude mixture as a stable solid (Scheme 3). The structure of **7b** structure was determined by NMR experiments (2D COSY, DEPT, HMQC) (for details, see the Supporting Information).

In order to maximize the formation of compound **7b** without having collateral reactions, a screening of reaction conditions was undertaken. We found that the use of catalytic amounts of several copper(I) salts (CuBr, CuCl, CuBr·SMe_2) in a non-nucleophilic solvent (THF, MeCN, DMF, toluene, CH_2Cl_2) afforded the desired bicyclic compound **7b**



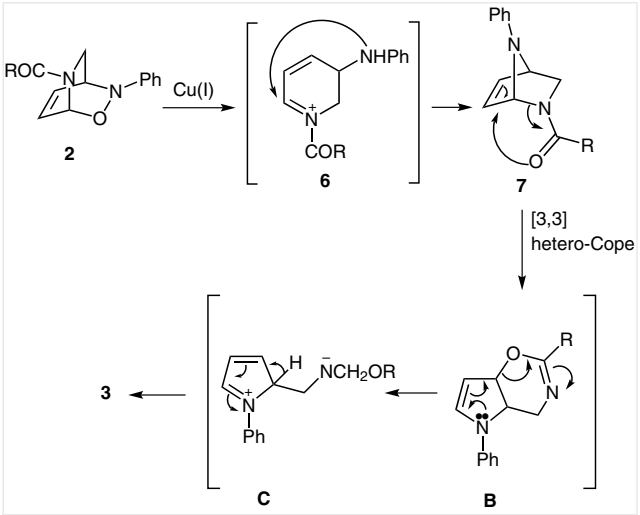
Scheme 2 Product distribution and origin of stereoselectivity starting from hemiaminal **4a**



Scheme 4 Optimized copper-catalyzed reactions

as the main product with the best results obtained using 20 mol% of CuCl in anhydrous CH_2Cl_2 in the presence of 3 equivalents of isopropyl alcohol. In this reaction conditions, it was possible to obtain compound **7b** with 65% isolated yield after a simple chromatographic purification on silica gel (Scheme 4). At this point, we were curious to test the stability of this unusual strained *gem*-diamine derivative (for details, see the Supporting Information). Interestingly, the treatment of a solution of compound **7b** in dichloroethane (DCE) at 75 °C in the presence of 0.2 equivalent of CuCl afforded pyrrole **3b** as the main product (Scheme 4). When the reaction was carried out in the same reaction conditions without the presence of CuCl, only decomposition products were obtained indicating the fundamental role exerted by copper(I) in this rearrangement.

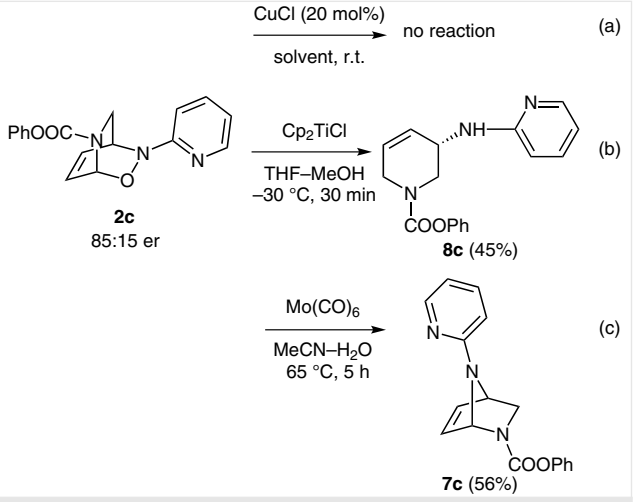
Therefore, the data obtained in this work support the notion that the preparation of pyrrole derivatives from phenylnitroso cycloadduct can occur by the intermediacy of 2,7-diazabicycloheptenes of type **7**. Thus, it is plausible that the initial copper-catalyzed cleavage of the N–O bond is followed by the putative formation of a conjugated *N*-acyliminium ion **6** that undergoes intramolecular amination to deliver the isolable 2,7-diazabicycloheptene **7** (Scheme 5).[10] A subsequent [3.3] hetero-Cope rearrangement could give a 4,4a,5,7a-tetrahydropyrrole[2,3-*e*]-1,3-oxazine derivative **B** that after electronic reorganization and aromatization can afford the pyrrole derivative **3**.[11] Probably, in the cases where the 1,2-dihydropyridine is protected with more electron-withdrawing groups, such as amide derivatives (R = Me, Ph),[5] the corresponding 2,7-diazabicycle heptene of type **7** can not be observed due to a plausible faster intramolecular amination-rearrangement process under copper-catalyzed conditions occurring also at room temperature. On the other hand, when using a protecting group possessing a lower electron-withdrawing ability (such as, R = OCH_2Ph) only a complex mixture of regioisomeric methoxy tetrahydropyridines using MeOH as the reaction solvent can be obtained.[5] The phenoxycarbonyl protection (R = OPh) seems to have the right balance of electron-withdrawing ability to allow the isolation of the corresponding strained bicyclic *gem*-diamine **7b** even in MeOH.



Scheme 5 Revised plausible mechanism for the formation of pyrrole derivatives catalyzed by copper(I) salts

The use of phenoxycarbonyl protected pyridine-nitroso cycloadduct **2c** revealed to be particularly interesting (Scheme 6). First of all, this compound was obtained in enantioenriched form (85:15 er) by the application of the asymmetric NDA reaction between 2-nitrosopyridine and 1,2-dihydropyridine **1b** catalyzed by 10 mol% of $[CuPF_6(MeCN)_4]$/Walphos-CF_3.[12] Another advantage of the use of pyridine nitroso derivatives resides in the possibility of deprotection to the free amine, thus circumventing the problems usually connected with the metabolism of aniline-derived compounds.[13] Compound **2c** showed to be unreactive with copper salts in solvents such as CH_2Cl_2 or MeOH due to a plausible chelation of the metal with the pyridine nitrogen and the oxygen of the bicycle (Scheme 6, a). On the other hand, the use of stoichiometric amounts of $Cp_2Ti(III)Cl$ at low temperatures,[5,14] readily afforded (30 min at –30 °C) 1,2,3,6-tetrahydropyridine **8c** resulting from the cleavage of the N–O bond followed by deoxygenation of the expected amino alcohol (Scheme 6, b). Considering the importance of 3-aminopiperidine in medicinal chemistry,[15,16] our approach allows the preparation of this class of compounds in enantioenriched form in a very simple manner.[17] Moreover, the presence of an adjacent double bond gives the possibility for further transformations of this drug-like scaffold. After screening of other reductive reaction condi-

tions by not contemplating the use of copper(I) salts, we found that the use of a stoichiometric amount of $Mo(CO)_6$ in a MeCN–H_2O mixture at 65 °C for few hours afforded the corresponding bicyclic *gem*-diamine **7c** (Scheme 6, c).



Scheme 6 Reductive cleavages of pyridine nitroso cycloadduct **2c**

In summary, we have established a simple and rapid access to novel 2,7-diazabicyclo[2.2.1]heptene derivatives of type **7** and 3-amino-1,2,3,6-tetrahydropyridine **8c**. These scaffolds can also be obtained in enantioenriched form and could be of interest in a diversity-oriented search for new bioactive compounds. We have also reported new experimental evidences on the mechanism of the manifold reactivity of nitroso Diels–Alder cycloadducts with 1,2-dihydropyridines by the use of transition metals.

All reagents were purchased from commercially available sources. The Zn dust was activated by washing it in a separatory funnel with 10% aq HCl, followed by H_2O, EtOH, Et_2O, and by drying overnight at 100 °C. Anhydrous CH_2Cl_2 (dried on molecular sieves) and MeOH (HPLC grade) were used as the reaction solvents without any further purification. THF was distilled on Na/benzophenone ketyl. Solvents for extraction and chromatography were distilled before use. TLC analyses were performed on silica gel sheets with detection by exposure to ultraviolet light (254 nm) and/or by immersion in an acidic staining solution of *p*-anisaldehyde in EtOH. Silica gel 60 was used for flash chromatography. Automated column chromatography was performed using prepacked silica gel cartridges on a Biotage Isolera 1.5.2 (27–53 µm). ^{1}H NMR spectra were recorded at 250 MHz. Chemical shifts are reported in ppm downfield from TMS with the solvent resonance as the internal standard ($CDCl_3$: δ = 7.26, CD_3CN: δ = 1.94). Standard signal patterns are used to indicate multiplicities. Coupling constants (*J*) are given in hertz (Hz). ^{13}C NMR spectra were recorded at 62.5 MHz, with complete proton decoupling. Chemical shifts are reported in ppm downfield from TMS with the solvent resonance as the internal standard ($CDCl_3$: δ = 77.16; CD_3CN: δ = 1.32). Melting points were determined on a Kofler apparatus and are uncorrected. HRMS-ESI were acquired in positive ion mode on a Q-TOF premier spectrometer equipped with a nanoelectrospray ion source.

CuCl-Catalyzed Methanolysis of Hemiaminal 4a

To a solution of **4a** (46 mg, 0.15 mmol) in MeOH (1.15 mL) was added anhydrous CuCl (3.0 mg, 0.03 mmol) and the mixture was allowed to react for 16 h at r.t. Removal of solvent in vacuum gave a residue, which was rinsed with CH_2Cl_2 and diluted with H_2O (1.0 mL). The aqueous layer was extracted with CH_2Cl_2 (3 × 4 mL) and the combined organic fractions were dried ($MgSO_4$), filtered, and concentrated. Subsequent flash chromatography (hexanes–EtOAc, 7:3) afforded the known compounds **5a**[5] (21 mg, 44%; R_f = 0.41), and **3a**[5] (2.6 mg, 6%; R_f = 0.22).

(1*S**,4*R**)-2-Phenyl-3-oxa-2,5-diazabicyclo[2.2.2]oct-7-ene-5-carboxylic Acid Phenyl Ester (2b)

A solution of 1,2-dihydropyridine **1b** (202 mg, 1.0 mmol) was dissolved in CH_2Cl_2 (2.0 mL) to give a yellowish solution. The subsequent addition of nitrosobenzene (215 mg, 2.0 mmol) turned the solution to dark green, and after 1 h of vigorous stirring, the removal of the solvent gave a crude solid, which was triturated with EtOAc to afford a white solid; yield: 256 mg (83%); mp 120–121 °C.

^{1}H NMR (250 MHz, $CDCl_3$): δ = 7.47–6.99 (m, 11 H), 6.86–6.74 (m, 1 H), 6.40–6.23 (m, 2 H), 4.72–4.61 (m, 1 H), 4.27 (dd, *J* = 10.7, 2.7 Hz, 1 H, major rotamer), 4.11 (dd, *J* = 11.0, 2.7 Hz, 1 H, minor rotamer), 3.52 (dd, *J* = 10.7, 2.1 Hz, 1 H, major rotamer), 3.40 (dd, *J* = 11.0, 2.1 Hz, 1 H, minor rotamer).

^{13}C NMR (63 MHz, $CDCl_3$): δ = 153.1, 152.3, 150.9, 150.4, 130.6, 130.1, 129.5, 129.5, 128.8, 127.6, 127.3, 125.7, 123.3, 121.7, 117.7, 117.6, 75.9, 75.1, 56.9, 56.9, 45.4, 45.2.

HRMS (ESI): *m*/*z* [M + Na^+] calcd for $C_{18}H_{16}N_2O_3$ + Na: 331.1053; found: 331.1050.

(1*S*,4*R*)-2-Pyridin-2-yl-3-oxa-2,5-diazabicyclo[2.2.2]oct-7-ene-5-carboxylic Acid Phenyl Ester (2c)

Following a modification of the previously described method,[12] a flame-dried 50 mL Schlenk tube was charged with (*R*,*Rp*)-Walphos-CF_3 ligand (78.7 mg, 0.082 mmol) and $[Cu(MeCN)_4]PF_6$ (31 mg, 0.082 mg) followed by CH_2Cl_2 (11.7 mL). The resulting yellow solution was stirred for 1 h and cooled to –78 °C and treated with 2-nitrosopyridine (86 mg, 0.82 mmol). Subsequently, a solution of **1b** (202 mg, 1 mmol) in CH_2Cl_2 (5.6 mL) was added dropwise over 1 h. A color change to dark brown was observed. The reaction mixture was allowed to stir for 90 min at –78 °C. The solvent was evaporated to give a solid crude, which was subjected to flash chromatography (hexanes–EtOAc, 6:4; R_f = 0.25) to give the title compound as a yellow solid; yield: 182 mg (71%); mp 116–117 °C; $[\alpha]_D^{20}$ –2.3 (*c* = 0.27, $CHCl_3$).

Enantiomeric ratio (85:15) was determined by HPLC on a Daicel Chiralcel OD-H column (hexane–*i*-PrOH, 90:10); flow rate: 0.5 mL/min; t_R (minor) = 33.3 min, t_R (major) = 51.9 min.

^{1}H NMR (250 MHz, $CDCl_3$): δ = 8.24 (d, *J* = 4.6 Hz, 1 H), 7.64–7.52 (m, 1 H), 7.44–7.29 (m, 2 H), 7.29–7.07 (m, 3 H), 6.97 (dd, *J* = 8.3, 2.5 Hz, 1 H), 6.87 (dd, *J* = 6.9, 5.2 Hz, 1 H), 6.71–6.59 (m, 1 H), 6.49–6.38 (m, 1 H), 6.36–6.25 (m, 1 H), 5.63–5.51 (m, 1 H), 4.19 (dd, *J* = 10.8, 2.8 Hz, 1 H, major rotamer), 3.55 (dd, *J* = 10.8, 2.1 Hz, 1 H, major rotamer).

^{13}C NMR (62.5 MHz, $CDCl_3$): δ = 162.6, 153.2, 150.9, 147.5, 147.4, 138.0, 138.0, 130.1, 129.9, 129.6, 129.5, 129.48, 125.8, 121.8, 117.9, 111.8, 111.7, 76.3, 75.6, 52.4, 52.3, 45.1, 44.9.

HRMS (ESI): *m*/*z* [M + Na$^+$] calcd for $C_{17}H_{15}N_3O_3$ + Na: 332.1006; found: 332.1003.

(1-Phenyl-1*H*-pyrrol-2-ylmethyl)carbamic Acid Phenyl Ester (3b)

A pyrex vial was charged with **7b** (59 mg, 0.20 mmol), CuCl (4.0 mg, 0.04 mmol), and 1,2-dichloroethane (1.55 mL), and placed in a preheated oil bath at 75 °C. The reaction mixture was allowed to stir for 18 h, filtered through a short pad of Celite, and washed several times with CH_2Cl_2. Removal of the solvent gave a semi-solid, which was subjected to flash chromatography (hexanes–EtOAc, 7:3) to give **3b** as an amorphous solid; yield: 44 mg (70%).

^{1}H NMR (250 MHz, $CDCl_3$): δ = 7.53–7.15 (m, 8 H), 7.03 (d, *J* = 7.5 Hz, 2 H), 6.84 (dd, *J* = 2.6, 1.8 Hz, 1 H), 6.33 (s, 1 H), 6.26 (t, *J* = 3.1 Hz, 1 H), 5.00 (br s, 1 H), 4.42 (d, *J* = 5.3 Hz, 2 H).

^{13}C NMR (62.5 MHz, $CDCl_3$): δ = 154.0, 151.1, 139.7, 129.6, 129.4, 129.3, 127.9, 126.1, 125.4, 123.5, 121.7, 109.9, 108.6, 37.7.

HRMS (ESI): *m*/*z* [M + Na$^+$] calcd for $C_{18}H_{16}N_2O_2$ + Na: 315.1104; found: 315.1101.

(1*S,4*S**)-7-Phenyl-2,7-diazabicyclo[2.2.1]hept-5-ene-2-carboxylic Acid Phenyl Ester (7b)**

A solution of cycloadduct **2b** (93 mg, 0.30 mmol) in CH_2Cl_2 (2.3 mL) was added with *i*-PrOH (69 µL, 0.90 mmol) and CuCl (5.9 mg, 0.06 mmol), and allowed to stir for 18 h at r.t. The reaction mixture was quenched with sat. aq NH_4Cl (3.0 mL) and the aqueous phase was extracted with CH_2Cl_2 (3 × 5.0 mL). The combined organic layers were dried ($MgSO_4$), and concentrated under vacuum. Flash chromatography (hexanes–EtOAc, 1:1; R_f = 0.16) afforded pure compound **7b** as a yellowish solid; yield: 62 mg (65%); mp 133–135 °C.

^{1}H NMR (250 MHz, $CDCl_3$): δ = 7.47–7.06 (m, 10 H), 6.77 (t, *J* = 7.3 Hz, 1 H), 6.69 (d, *J* = 7.8 Hz, 2 H), 6.09 (d, *J* = 10.1 Hz, 1 H), 6.02–5.79 (m, 2 H), 4.52 (dd, *J* = 12.4, 5.5 Hz, 1 H), 4.22 (br s, 1 H), 3.17–2.84 (m, 1 H).

^{13}C NMR (62.5 MHz, $CDCl_3$): δ = 150.9, 146.2, 133.3, 129.7, 129.6, 127.1, 126.0, 121.8, 118.6, 113.6, 73.2, 47.9, 42.7.

HRMS (ESI): *m*/*z* [M + Na$^+$] calcd for $C_{18}H_{16}N_2O_2$ + Na: 315.1104; found: 315.1108.

(1*S*,4*R*)-7-Pyridin-2-yl-2,7-diazabicyclo[2.2.1]hept-5-ene-2-carboxylic Acid Phenyl Ester (7c)

A 10 mL pyrex vial was charged with a solution of racemic **2c** (62 mg, 0.20 mmol) in MeCN (1 mL). H_2O (60 µL, 3.33 mmol) and $Mo(CO)_6$ (65 mg, 0.24 mmol) were added to give a heterogeneous yellow solution. The reaction mixture was placed in a preheated oil bath at 65 °C and stirred for 2.5 h. Upon heating, a color change to dark green was observed. The mixture was filtered through a short pad of Celite and washed several times with CH_2Cl_2. The filtrate was concentrated and the residue was purified by flash chromatography (hexanes–EtOAc, 3:7; R_f = 0.26) to give compound **7c** as a white solid; yield: 33 mg (56%); mp 112–114 °C.

^{1}H NMR (250 MHz, CD_3CN): δ = 8.10–7.99 (m, 1 H), 7.50–7.13 (m, 5 H), 6.64–6.48 (m, 2 H), 6.08–5.94 (m, 1 H), 5.94–5.75 (m, 2 H), 5.12 (s, 1 H), 4.76–4.61 (m, 1 H), 4.44 (dd, *J* = 12.4, 5.4 Hz, 1 H), 4.08 (s, 1 H), 2.99 (t, *J* = 11.4 Hz, 1 H).

^{13}C NMR (62.5 MHz, $CDCl_3$): δ (major rotamer) = 157.4, 151.0, 148.3, 137.8 133.2, 129.5, 129.4, 127.2, 125.9, 121.9, 113.9, 108.6, 73.1, 46.2, 42.5.

HRMS (ESI): *m*/*z* [M + Na$^+$] calcd for $C_{17}H_{15}N_3O_2$ + Na: 316.1056; found: 316.1052.

(3*R*)-3-(Pyridin-2-ylamino)-3,6-dihydro-2*H*-pyridine-1-carboxylic Acid Phenyl Ester (8c)

In a 10 mL flame-dried Schlenk tube, Cp_2TiCl_2 (127 mg, 0.496 mmol) was diluted, under argon protection, with of freshly distilled THF (2.5 mL). After the addition of activated Zn dust (66 mg, 0.99 mmol), the reaction mixture was stirred at r.t. for 50 min and then cooled to –30 °C. A solution of **2c** (61 mg, 0.2 mmol) in MeOH (2.0 mL) was added over 5 min and the resulting solution was allowed to stir for 30 min at –30 °C. The reaction was quenched with H_2O (6.5 mL), followed by sat. aq $NaHCO_3$ (2.0 mL), and allowed to reach r.t. The aqueous phase was extracted with EtOAc (3 × 8 mL) and the combined organic layers were dried ($MgSO_4$), filtered, and concentrated. Subsequent flash chromatography (hexane–EtOAc, 1:1; R_f = 0.22) afforded the title compound as a white amorphous semi-solid; yield: 27 mg (45%); $[\alpha]_D^{20}$ +6.3 (*c* = 0.24, $CHCl_3$).

Enantiomeric ratio (>90:<10, not complete baseline separation) was determined by HPLC on a Daicel Chiralpak AD-H column (hexane–i-PrOH, 90:10); flow rate 1.0 mL/min; tR (minor) = 17.7 min, t_R (major) = 16.9 min.

^{1}H NMR (250 MHz, $CDCl_3$): δ = 8.09 (s, 1 H), 7.50–6.86 (m, 3 H), 6.60 (dd, *J* = 12.3, 6.8 Hz, 1 H), 6.44 (d, *J* = 8.3 Hz, 1 H), 5.99 (d, *J* = 13.0 Hz, 1 H), 4.58 (s, 1 H), 4.37–3.40 (m, 2 H).

^{13}C NMR (62.5 MHz, $CDCl_3$): δ = 157.5, 154.3, 151.4, 148.3, 148.2, 137.8, 137.6, 129.5, 129.3, 127.8, 126.8, 126.4, 125.8, 125.3, 121.7, 113.9, 113.6, 108.3, 108.0, 46.1, 45.6, 43.8.

HRMS (ESI): *m*/*z* [M + Na$^+$] Calcd for $C_{17}H_{17}N_3O_2$ + Na: 318.1213; found: 318.1217.

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Supporting Information

Supporting information for this article is available online at http://dx.doi.org/10.1055/s-0034-1378682.

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