Available online at www.sciencedirect.com
ScienceDirect
Tetrahedron Letters
Tetrahedron Letters 47 (2006) 7331–7334

Novel imidazolium chiral ionic liquids that contain a urea functionality

Bukuo Ni and Allan D. Headley*

Department of Chemistry, Texas A&M University-Commerce Commerce, TX 75429-3011, USA

Received 21 July 2006; revised 4 August 2006; accepted 7 August 2006
Available online 24 August 2006

Abstract—Nine chiral room temperature ionic liquids (RTILs), which contain a chiral moiety and a urea functionality bonded to a imidazolium ring, have been designed and synthesized. The synthesis of these ionic liquids is concise and practical due to the commercial availability of the starting materials. These novel RTILs were readily prepared from 1-(3-aminopropyl)imidazole and amino acid ester derived isocyanates. We envision that these new chiral RTILs can serve as effective reaction media as well as chiral catalysts, which are presently being investigated in our laboratory.

Recently, the interest in using room temperature ionic liquids (RTILs) as solvents for organic synthesis has increased dramatically.[1] Compared to conventional solvents, RTILs are recyclable, thermally stable over a very wide temperature range, and some maintain their liquid state at temperatures as high as 200 °C.[2] It is due to this unique combination of properties that they have become the solvents of choice for green chemistry and are used for a wide variety of reactions.[3] RTILs consist of cations and anions counterparts; cations are typically imidazolium or pyridium species and anions normally include halogen anions, AlX_4^-, BF_4^-, PF_6^-, $CF_3SO_3^-$ or $(CF_3SO_3)_2N^-$. The modification of the structures of the cations or anions of ionic liquids can result in unique solvent properties that can alter the outcomes of various reactions, including asymmetric reactions.

Even though a limited number of chiral RTILs have been designed and synthesized in an attempt to influence the outcomes of asymmetric organic reactions,[4] there are only a few chiral ionic liquids that can effectively influence the outcomes of asymmetric reactions.[5] A thorough literature review reveals that the design of existing chiral RTILs is based on modifications of the ammonium,[6] pyridinium,[7] oxazolinium,[7a] or thiazolium cations.[8] There are several chiral RTILs in which the chiral moiety is contained in the anion (**I**–**II**)[9] (Fig. 1), but the modification of imidazolium cation-derived RTILs offers extreme promise in the design of chiral RTILs due to their facile preparation, low melting points, and relatively favorable viscosity. Shown in Figure 1 are some imidazole-derived chiral RTILs that have been used as solvents, they contain chiral moieties bonded to one or both of the nitrogen atoms on positions 1 and 3 of the imidazolium cation (**III**–**VII**).[10] Imidazolium ionic liquids with chirality bonded to the 4 position (**VIII**)[11] and bonded to the 2 position with a spiro skeleton (**IX**)[12] have also been prepared.

Our recent interest in this field is to design and synthesize chiral RTILs that contain the imidazolium moiety, as well as exhibit the ability to form hydrogen bonds to reactants and intermediates.[13] Urea derivatives have been used extensively as efficient Lewis-acidic catalysts for organic transformations due to effective H-bonds that are formed via the amide hydrogens. Due to the acidic hydrogens in urea compounds that contain electron-withdrawing substituents, stable cocrystals with a variety of proton acceptors, including carbonyl compounds, are readily formed. For example, Maher and Connon have demonstrated that catalytic amounts of bis-aryl ureas can be used to accelerate the Baylis–Hillman reaction.[14] Berkessel et al. have demonstrated that dynamic kinetic resolution of azlactones by urea-based organocatalysts with high enantioselectivity is possible,[15] and Jacobsen and co-workers have utilized urea derivatives as catalysts for a variety of reactions.[16] In

Keywords: Ionic liquid; Chiral solvents; Asymmetric reactions; Green chemistry.
* Corresponding author. Tel.: +1 9038865159; fax: +1 9038865165; e-mail: allan_headley@TAMU-Commerce.edu

0040-4039/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.tetlet.2006.08.015

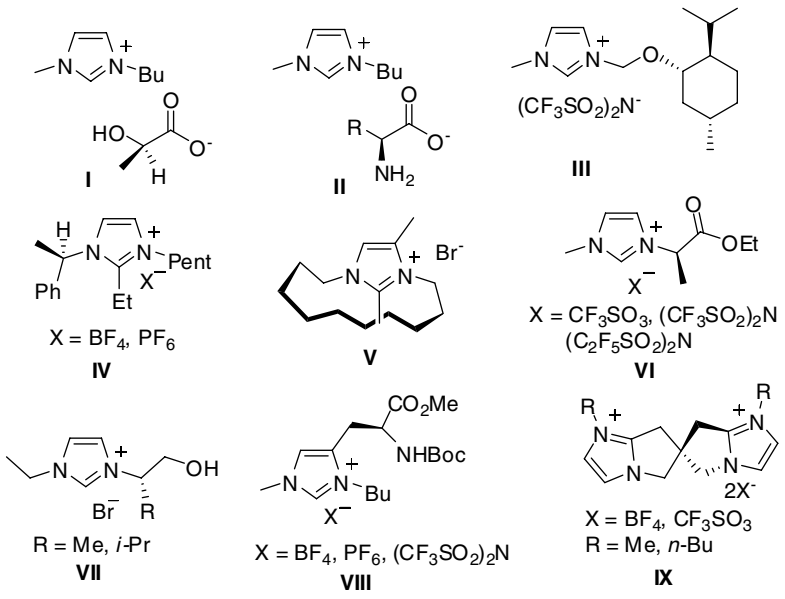
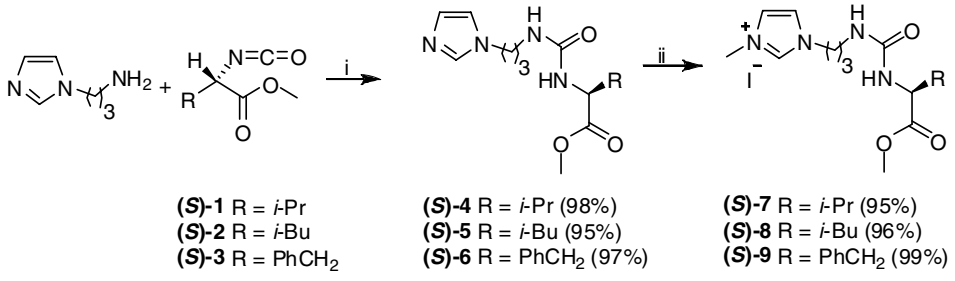


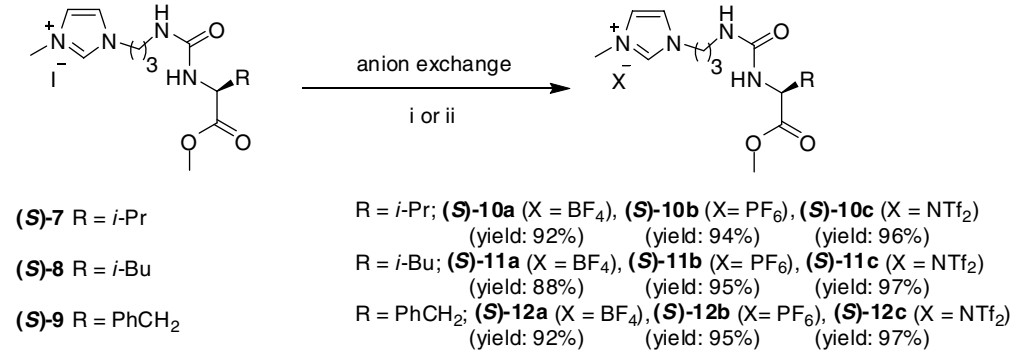
Figure 1. Chiral imidazolium ionic liquids.

this report, we have designed a unique series of chiral RTILs that contain the imidazolium cation, a chiral moiety, and also embedded is a urea unit (Scheme 1). The present design is concise and practical due to the ready availability and low cost of the starting materials. This is the first time that the urea unit has been introduced into the imidazolium cation of chiral ionic liquids in an effort to influence the outcomes of asymmetric reactions.

As shown in Scheme 1, 1-(3-aminopropyl)imidazole was treated with substituted (*S*)-(−)-2-isocynato-3-methylbutyrate to yield the desired urea with excellent yields (95–97%). The alkylation salt formation was carried out by heating pyridine urea derivatives (*S*)-**4**–(*S*)-**6** with one equivalent of iodomethane at 40 °C in neat for 24 h to form the imidazolium iodine salts (*S*)-**7**–(*S*)-**9** in 96–99% yield. The next step of the synthesis involves the transformation of pyridinium iodide salts to ionic liq-



Scheme 1. Reagents and conditions: (i) CH_2Cl_2, rt, 24 h; (ii) iodomethane, 40 °C, 20 h.



Scheme 2. Reagents and conditions: (i) KBF_4, MeOH–H_2O, rt, 2 d; (ii) KPF_6 or Tf_2NLi, H_2O, rt, 1 h.

uids (*S*)-**10a**–(*S*)-**12c** by anion exchange of (*S*)-**7**–(*S*)-**9** with different anions (BF_4^-, PF_6^-, $(CF_3SO_2)_2N^-$)—Scheme 2.

Chiral imidazolium tetrafluoroborates (*S*)-**10a**–(*S*)-**12a** were prepared by the treatment of their precursors, imidazolium iodide (*S*)-**7**–(*S*)-**9**, with potassium tetrafluoroborate in methanol and water at room temperature for 2 days in 88–92% yields after purification. Chiral imidazolium hexafluorophosphates (*S*)-**10b**–(*S*)-**12b** were also readily obtained by anion exchange of imidazolium iodine (*S*)-**7**–(*S*)-**9** with potassium hexafluorophosphate in H_2O at room temperature for 1 h in 94–95% yields. Similarly, imidazolium bis(trifluoromethylsulfonyl)imides (*S*)-**10c**–(*S*)-**12c** were obtained in 96–97% yields (Scheme 2).[17]

In summary, we have designed and synthesized nine chiral room temperature imidazolium ionic liquids, which contain a chiral moiety tethered to a urea functionality. These novel RTILs can readily be prepared from 1-(3-aminopropyl)imidazole and amino acid ester derived isocyanates. The synthesis is concise and practical due to the commercial availability of the starting materials and convenient reaction conditions of their synthesis. We envision that these new chiral RTILs will serve as effective solvents, as well as chiral catalysts for a variety of asymmetric reactions, which are currently being investigated in our laboratories.

Acknowledgment

This work was supported by the Robert A. Welch Foundation (T-1460).

References and notes

1. For review see: (a) Welton, T. *Chem. Rev.* **1999**, *99*, 2071; (b) Dupont, J.; de Souza, R. F.; Suarez, P. A. Z. *Chem. Rev.* **2002**, *102*, 3667; (c) Wasserscheid, P.; Welton, T. *Ionic Liquids in Synthesis*; Wiley-VCH: Weinheim, Germany, 2003; (d) Rogers, R. D.; Seddon, K. R.; Volkov, S. *Green Industrial Applications of Ionic Liquids*; Kluwer Academic: Dordrecht, 2002; (e) Baudequin, C.; Baudoux, J.; Levillain, J.; Cahard, D.; Gaumontb, A. C.; Plaqueventa, J. C. *Tetrahedron: Asymmetry* **2003**, *14*, 3081; (f) Freemantle, M. *Chem. Eng. News* **2004**, *82*, 44.
2. (a) Park, S.; Kazlauskas, R. J. *J. Org. Chem.* **2001**, *66*, 8395; (b) Chiappe, C.; Pieraccini, D. *J. Phys. Org. Chem.* **2005**, *18*, 275; (c) Freemantle, M. *Chem. Eng. News* **1998**, *76*, 32; (d) Wilkes, J. S. *Green Chem.* **2002**, *4*, 73.
3. (a) Wasserscheid, P.; Keim, W. *Angew. Chem., Int. Ed.* **2000**, *39*, 3772; (b) Handy, S. T. *Chem. Eur. J.* **2003**, *9*, 2938; (c) Sheldon, R. *Chem. Commun.* **2001**, 2399; (d) Meracz, I.; Oh, T. *Tetrahedron Lett.* **2003**, *44*, 6465; (e) Handy, S. T.; OKello, M. *Tetrahedron Lett.* **2003**, *45*, 8399; (f) Dzyuba, S. V.; Bartsch, R. A. *Tetrahedron Lett.* **2002**, *43*, 4657; (g) Xiao, J.-C.; Shreeve, J. M. *J. Org. Chem.* **2005**, *70*, 3072; (h) Xu, X.; Kotti, S. R. S. S.; Liu, J.; Cannon, J. F.; Headley, A. D.; Li, G. *Org. Lett.* **2004**, *6*, 4881; (i) Kotti, S. R. S. S.; Xu, X.; Wang, Y.; Headley, A. D.; Li, G. *Tetrahedron Lett.* **2004**, *45*, 7209; (j) Kabalka, G. W.; Venkataiah, B.; Das, B. C. *Synlett* **2003**, *12*, 2194; (k) Kabalka, G. W.; Venkataiah, B.; Dong, G. *Tetrahedron Lett.* **2003**, *44*, 4673; (l) Zhao, H.; Malhotra, S. V. *Biotechnol. Lett.* **2002**, *24*, 1257; (m) Zhao, H.; Malhotra, S. V. *Aldrichim. Acta* **2002**, *35*, 75; (n) Laali, K. K.; Gettwert, V. J. *J. Org. Chem.* **2001**, *66*, 35; (o) Davis, J. H.; Forrester, J. K. J. *Tetrahedron Lett.* **1998**, *39*, 8955.
4. (a) Earle, M. J.; McCormac, P. B.; Seddon, K. R. *Green Chem.* **1999**, *1*, 23; (b) Pégot, B.; Vo-Thanh, G.; Gori, D.; Lopy, A. *Tetrahedron Lett.* **2004**, *45*, 6425; (c) Wang, Z.; Wang, Q.; Zhang, Y.; Bao, W. *Tetrahedron Lett.* **2005**, *46*, 4657.
5. Ding, J.; Armstrong, D. W. *Chirality* **2005**, *17*, 281, and references cited therein.
6. (a) Wasserscheid, P.; Bosmann, A.; Bolm, C. *Chem. Commun.* **2002**, 200; (b) Thanh, G. V.; Pegot, B.; Loupy, A. *Eur. J. Org. Chem.* **2004**, 1112; (c) Pernak, J.; Feder-Kubis, J. *Chem. Eur. J.* **2005**, *11*, 4441.
7. (a) Baudequin, C.; Baudoux, J.; Levillian, J.; Cahard, D.; Gaumont, A. C.; Plaquevent, J. C. *Tetrahedron: Asymmetry* **2003**, *14*, 3081; (b) Haramoto, Y.; Miyashita, T.; Nanasawa, M.; Aoki, Y.; Nohira, H. *Liq. Cryst.* **2002**, *29*, 87; (c) Baudoux, J.; Judeinstein, P.; Cahard, D.; Plaquevent, J.-C. *Tetrahedron Lett.* **2005**, *46*, 1137; (d) Patrascu, C.; Sugisaki, C.; Mintogaud, C.; Marty, J.-D.; Génisson, Y.; Lauth de Viguerie, N. *Heterocycles* **2004**, *63*, 2033; (e) Fringuelli, F.; Pizzo, F.; Tortoioli, S.; Vaccaro, L. *J. Org. Chem.* **2004**, *69*, 7745; (f) Drahonovasky, D.; Labat, G. C.; Sevick, J.; von Zelewsky, A. *Heterocycles* **2005**, *65*, 2169; (g) Tosoni, M.; Laschat, S.; Baro, A. *Helv. Chim. Acta* **2004**, *87*, 2742.
8. Levillian, J.; Dubant, G.; Abrunhosa, I.; Gulea, M.; Gaumont, A. C. *Chem. Commun.* **2003**, 2914.
9. (a) Earle, M. J.; McCormac, P. B.; Seddon, K. R. *Green Chem.* **1999**, *1*, 23; (b) Pernak, J.; Goc, I.; Mirska, I. *Green Chem.* **2004**, *6*, 323; (c) Fukumoto, K.; Yoshizawa, M.; Ohno, H. *J. Am. Chem. Soc.* **2005**, *127*, 2398–2399.
10. (a) Howarth, J.; Hanlon, K.; Fayne, D.; McCormac, P. *Tetrahedron Lett.* **1997**, *38*, 3097; (b) Bao, W.; Wang, Z.; Li, Y. *J. Org. Chem.* **2003**, *68*, 591; (c) Jodry, J. J.; Mikami, K. *Tetrahedron Lett.* **2004**, *45*, 2033; (d) Tosoni, M.; Laschat, S.; Baro, A. *Helv. Chim. Acta* **2004**, *87*, 2742; (e) Kim, E. J.; Ko, S. Y.; Dziadulewicz, E. K. *Tetrahedron Lett.* **2005**, *46*, 631; (f) Génisson, Y.; Viguerie, L.-de.; Andre, C.; Baltas, M.; Gorrichon, L. *Tetrahedron: Asymmetry* **2005**, *16*, 1017.
11. Guillen, F.; Brégeon, D.; Plaquevent, J.-C. *Tetrahedron Lett.* **2006**, *47*, 1245.
12. Patil, M. L.; Rao, C. V. L.; Yonezawa, K.; Takizawa, S.; Onitsuka, K.; Sasai, H. *Org. Lett.* **2006**, *8*, 227.
13. Ni, B.; Headley, A. D.; Li, G. *J. Org. Chem.* **2005**, *70*, 10600.
14. Maher, D. J.; Connon, S. J. *Tetrahedron Lett.* **2004**, *45*, 1301.
15. Berkessel, A.; Cleemann, F.; Mukherjee, S.; Müller, T. H.; Lex, J. *Angew. Chem., Int. Ed.* **2005**, *44*, 807.
16. (a) Sigman, M. S.; Jacobsen, E. N. *J. Am. Chem. Soc.* **1998**, *120*, 4901; (b) Sigman, M. S.; Vachal, P.; Jacobsen, E. N. *Angew. Chem., Int. Ed.* **2000**, *39*, 1279; (c) Yoon, T. P.; Jacobsen, E. N. *Angew. Chem., Int. Ed.* **2005**, *44*, 466.
17. For the detail experimental procedure see Ref. 13. Analytical data: (*S*)-**10a** $[\alpha]_D^{20}$ −8.2 (*c* 0.74, EtOH); ^1H NMR (300 MHz, $CDCl_3$) δ 9.43 (s, 1H), 7.69 (s, 1H), 7.45 (s, 1H), 6.49 (t, $J = 5.7$ Hz, 1H), 5.99 (d, $J = 5.1$ Hz, 1H), 4.50–5.35 (m, 2H), 4.22 (dd, $J = 7.8$ and 5.1 Hz, 1H), 4.05 (s, 3H), 3.71 (s, 3H), 3.35–3.10 (m, 2H), 2.20–2.00 (m, 3H), 0.99 (d, $J = 5.1$ Hz, 3H), 0.97 (d, $J = 5.1$ Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 173.9, 158.8, 136.7, 123.6, 122.7, 58.6, 51.9, 47.4, 36.9, 36.0, 30.4, 30.3, 19.3, 18.2; IR

(neat) $v = 3306$, 1736, 1665, 1552, 1166 cm^{-1}; HRMS (ESI+) m/z (%) calcd for $[C_{14}H_{25}N_4O_3]^+$: 297.1927, found: 297.1928. (*S*)-**10b** (814 mg, 94%) as a yellow oil; $[\alpha]_D^{20}$ −8.3 (*c* 0.72, EtOH); ^1H NMR (400 MHz, MeOD-d_4) δ 8.78 (s, 1H), 7.59 (d, $J = 2.0$ Hz, 1H), 7.51 (d, $J = 2.0$ Hz, 1H), 4.23 (t, $J = 7.2$ Hz, 2H), 4.16 (d, $J = 5.2$ Hz, 1H), 3.91 (s, 3H), 3.71 (s, 3H), 3.24–3.10 (m, 2H), 2.16–1.98 (m, 3H), 0.95 (d, $J = 6.8$ Hz, 3H), 0.91 (d, $J = 6.8$ Hz, 3H); ^{13}C NMR (100 MHz, MeOD-d_4) δ 174.9, 160.8, 138.0, 124.9, 123.5, 59.8, 52.4, 48.1, 37.2, 36.4, 31.8, 31.7, 19.5, 18.1; IR (neat) $v = 1736$, 1642, 1564, 834 cm^{-1}; HRMS (ESI+) m/z (%) calcd for $[C_{14}H_{25}N_4O_3]^+$: 297.1927, found: 297.1937; HRMS (ESI−) m/z (%) calcd for $[PF_6]^-$: 144.9642, found: 144.9893. (*S*)-**10c** $[\alpha]_D^{20}$ −6.7 (*c* 1.11, EtOH); ^1H NMR (400 MHz, MeOD-d_4) δ 8.84 (s, 1H), 7.62 (t, $J = 2.0$ Hz, 1H), 7.54 (t, $J = 2.0$ Hz, 1H), 4.23 (t, $J = 6.8$ Hz, 2H), 4.17 (d, $J = 5.4$ Hz, 1H), 3.91 (s, 3H), 3.71 (s, 3H), 3.23–3.10 (m, 2H), 2.16–1.98 (m, 3H), 0.95 (d, $J = 6.8$ Hz, 3H), 0.91 (d, $J = 6.8$ Hz, 3H); ^{13}C NMR (100 MHz, MeOD-d_4) δ 174.9, 160.9, 138.1, 125.0, 123.6, 121.2 (q,$J = 319.3$ Hz), 59.8, 52.4, 48.2, 37.2, 36.5, 31.9, 19.5, 18.1; IR (neat) $v = 1738$, 1642, 1564, 1187, 1056 cm^{-1}; HRMS (ESI+) m/z (%) calcd for $[C_{14}H_{25}N_4O_3]^+$: 297.1927, found: 297.1918; HRMS (ESI−) m/z (%) calcd for $[N(SO_2CF_3)_2]^-$: 279.9173, found: 279.9185. (*S*)-**11a**: Yield: 88%; yellow oil; $[\alpha]_D^{20}$ −13.3 (*c* 0.73, EtOH); ^1H NMR (400 MHz, MeOD-d_4) δ 8.96 (s, 1H), 7.66 (d, $J = 1.6$ Hz, 1H), 7.58 (d, $J = 1.6$ Hz, 1H), 4.30–4.25 (m, 3H), 3.94 (s, 3H), 3.71 (s, 3H), 3.25–3.10 (m, 2H), 2.10–2.00 (m, 2H), 1.78–1.68 (m, 1H), 1.56 (t, $J = 7.2$ Hz, 2H), 0.95 (d, $J = 6.8$ Hz, 3H), 0.93 (d, $J = 6.8$ Hz, 3H); ^{13}C NMR (100 MHz, MeOD-d_4) δ 176.1, 160.7, 138.2, 125.0, 123.7, 52.9, 52.6, 41.9, 37.2, 36.7, 31.8, 26.0, 23.3, 21.9; IR (neat) $v = 2954$, 1739, 1659, 1644, 1167 cm^{-1}; HRMS (ESI+) m/z (%) calcd for $[C_{15}H_{27}N_4O_3]^+$: 311.2083, found: 311.2078. (*S*)-**11b**: Yield: 85%; yellow solid; $[\alpha]_D^{20}$ −10.2 (*c* 1.03, EtOH); ^1H NMR (400 MHz, MeOD-d_4) δ 8.83 (s, 1H), 7.64 (d, $J = 1.6$ Hz, 1H), 7.56 (d, $J = 1.6$ Hz, 1H), 4.35–4.25 (m, 3H), 3.95 (s, 3H), 3.75 (s, 3H), 3.28–3.12 (m, 2H), 2.15–2.00 (m, 2H), 1.80–1.68 (m, 1H), 1.65–1.50 (m, 2H), 0.99 (d, $J = 6.8$ Hz, 3H), 0.96 (d, $J = 6.8$ Hz, 3H); ^{13}C NMR (100 MHz, MeOD-d_4) δ 176.1, 160.7, 138.1, 124.9, 123.6, 52.9, 52.6, 41.9, 37.2, 36.5, 31.7, 25.9, 23.3, 21.9; IR (neat) $v = 1739$, 1642, 1169, 835 cm^{-1}; HRMS (ESI+) m/z (%) calcd for $[C_{15}H_{27}N_4O_3]^+$: 311.2083, found: 311.2081; HRMS (ESI−) m/z (%) calcd for $[PF_6]^-$: 144.9642, found: 144.9668. (*S*)-**11c**: Yield: 97%. yellow oil; $[\alpha]_D^{20}$ −10.8 (*c* 1.14, EtOH); ^1H NMR (400 MHz, MeOD-d_4) δ 8.84 (s, 1H), 7.62 (s, 1H), 7.54 (s, 1H), 4.30–4.20 (m, 3H), 3.91 (s, 3H), 3.71 (s, 3H), 3.24–3.08 (m, 2H), 2.10–1.97 (m, 2H), 1.75–1.65 (m, 1H), 1.63–1.48 (m, 2H), 0.95 (d, $J = 6.8$ Hz, 3H), 0.93 (d, $J = 6.8$ Hz, 3H);^{13}C NMR (100 MHz, MeOD-d_4) δ 176.1, 160.7, 138.1, 125.0, 123.6, 121.1 (q, $J = 318.5$ Hz), 52.9, 52.6, 41.9, 37.2, 36.5, 31.8, 25.9, 23.3, 21.8; IR (neat) $v = 1739$, 1644, 1563, 1188, 1056 cm^{-1}; HRMS (ESI+) m/z (%) calcd for $[C_{15}H_{27}N_4O_3]^+$: 311.2083, found: 311.2088; HRMS (ESI−) m/z (%) calcd for $[N(SO_2CF_3)_2]^-$: 279.9173, found: 279.9189. (*S*)-**12a**: Yield: 92%; yellow oil; $[\alpha]_D^{20}$ −1.3 (*c* 1.30, EtOH); ^1H NMR (400 MHz, MeOD-d_4) δ 8.88 (s, 1H), 7.61 (s, 1H), 7.54 (s, 1H), 7.30–7.18 (m, 5H), 4.58–4.52 (m, 1H), 4.26–4.12 (m, 2H), 3.91 (s, 3H), 3.70 (s, 3H), 3.15–3.05 (m, 3H), 3.00–2.92 (m, 1H), 2.04–1.96 (m, 2H); ^{13}C NMR (100 MHz, MeOD-d_4) δ 174.6, 160.3, 138.2, 138.1, 130.4, 129.5, 127.9, 124.9, 123.6, 55.9, 52.7, 39.0, 37.1, 36.8, 31.7; IR (neat) $v = 3296$, 1739, 1664, 1552, 1167 cm^{-1}; HRMS (ESI+) m/z (%) calcd for $[C_{18}H_{25}N_4O_3]^+$: 345.1927, found: 345.1930. (*S*)-**12b**: Yield: 95%; yellow oil; $[\alpha]_D^{20}$ 3.2 (*c* 0.98, EtOH); ^1H NMR (400 MHz, MeOD-d_4) δ 8.71 (s, 1H), 7.54 (s, 1H), 7.48 (s, 1H), 7.32–7.16 (m, 5H), 4.54 (d, $J = 8.0$ and 5.2 Hz, 1H), 4.20–4.06 (m, 2H), 3.88 (s, 3H), 3.69 (s, 3H), 3.15–3.05 (m, 3H), 2.98–2.90 (m, 1H), 2.02–1.92 (m, 2H); ^{13}C NMR (100 MHz, MeOD-d_4) δ 174.7, 160.3, 138.2, 130.3, 129.5, 127.9, 124.9, 123.5, 55.8, 52.7, 39.0, 37.1, 36.4, 31.7; IR (neat) $v = 1739$, 1641, 1169, 835 cm^{-1}; HRMS (ESI+) m/z (%) calcd for $[C_{18}H_{25}N_4O_3]^+$: 345.1927, found: 345.1939; HRMS (ESI−) m/z (%) calcd for $[PF_6]^-$: 144.9642, found: 144.9651. (*S*)-**12c**: Yield: 97%; yellow oil; $[\alpha]_D^{20}$ 0.8 (*c* 1.00, EtOH); ^1H NMR (400 MHz, MeOD-d_4) δ 8.76 (s, 1H), 7.58–7.48 (m, 2H), 7.32–7.16 (m, 5H), 4.54 (dd, $J = 8.0$ and 5.2 Hz, 2H), 4.20–4.08 (m, 2H), 3.89 (s, 3H), 3.70 (s, 3H), 3.15–3.05 (m, 3H), 2.98–2.90 (m, 1H), 2.02–1.94 (m, 2H); ^{13}C NMR (100 MHz, MeOD-d_4) δ 174.6, 160.3, 138.1, 131.1, 130.3, 129.5, 127.9, 124.9, 123.4, 121.6 (q, $J = 319.3$ Hz), 55.8, 52.7, 39.0, 37.1, 36.5, 31.7; IR (neat) $v = 1740$, 1660, 1565, 1188,1056 cm^{-1}; HRMS (ESI+) m/z (%) calcd for $[C_{18}H_{25}N_4O_3]^+$: 345.1927, found: 345.1922; HRMS (ESI−) m/z (%) calcd for $[N(SO_2CF_3)_2]^-$: 279.9173, found: 279.9191.