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Stereoselective synthesis of trifluoromethyl-substituted 1,2-diamines by aza-Michael reaction with *trans*-3,3,3-trifluoro-1-nitropropene

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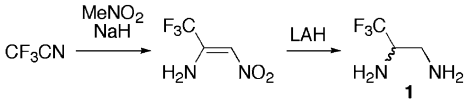
Abstract—Aza-Michael addition of optically pure 4-phenyl-2-oxazolidinone to 3,3,3-trifluoro-1-nitropropene proceeds smoothly at low temperature with a high yield. Diastereoselectivity of the addition depends on the base used and lithiated species proved to be highly efficient affording 92% de. Optically pure 1,2-diamino-3,3,3-trifluoropropane is prepared in 58% yield from the aza-Michael addition product through a three-step procedure.

1. Introduction

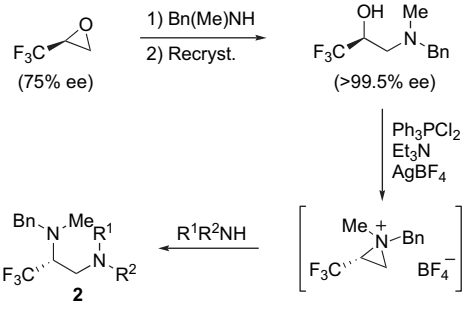
For more than 50 years fluorinated compounds receive tremendous interest as candidates for new pharmaceuticals and agrochemicals.[1] Today 16–17% of pharmaceuticals do incorporate fluorine and half of agrochemicals are fluorinated molecules. During the past decade, the number of fluorinated compounds developed by companies increased by a 2-fold factor and more and more investigations are now focusing toward chiral and optically pure fluorinated molecules.[2]

The synthesis of selectively fluorinated non-racemic chiral compounds having sophisticated structures is generally realized by fluorinating the final intermediate during the synthetic sequence. The synthesis of organofluorine compounds using fluorine-containing 'building blocks' is an efficient alternative to the direct introduction of fluorine. Although there has been recent general interest in the preparation and utilization of optically enriched and/or pure building blocks, there are, however, very few optically active and synthetically usable fluorinated compounds that are commercially available. Thus efforts, more than ever, are required to develop efficient methodologies to produce such compounds.

1,2-Ethylenediamines are key starting materials in the synthesis of nitrogen-containing heterocyclic compounds[3] (piperazines, imidazolines, imidazolidines, etc.) as well as aliphatic amines[4] (amino acids, amino alcohols, etc.). Chiral 1-trifluoromethyl-substituted 1,2-ethylenediamines especially gained our attention as promising building blocks for the synthesis of optically active trifluoromethylated nitrogen compounds. The synthesis of racemic 1,2-diamino-3,3,3-trifluoropropane **1** has been reported only very recently by Sosnovskikh et al.[5] The authors prepared the compound according to Scheme 1 by reduction of 2-amino-3,3,3-trifluoro-1-nitropropene with lithium aluminum hydride, and characterized **1** as bis-tosyl derivative.[6] At the same time



Scheme 1.



Scheme 2.

Keywords: Perfluoroalkyl nitroalkene; Diastereoselective aza-Michael addition; 3,3,3-Trifluoro-1-nitropropene; 4-Phenyl-2-oxazolidinone.
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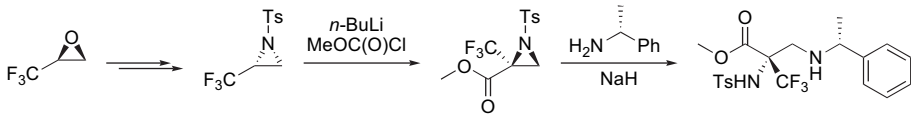
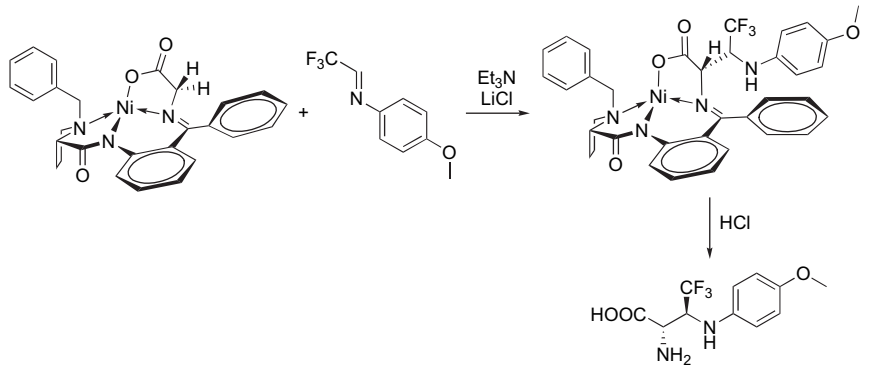
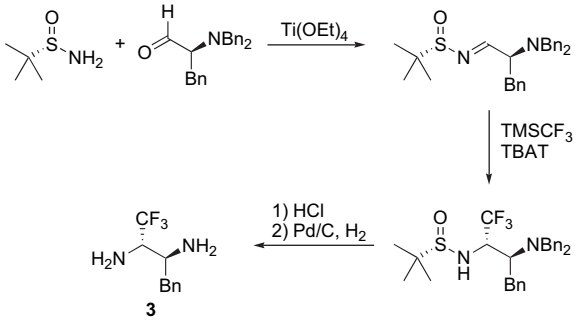


Scheme 3.

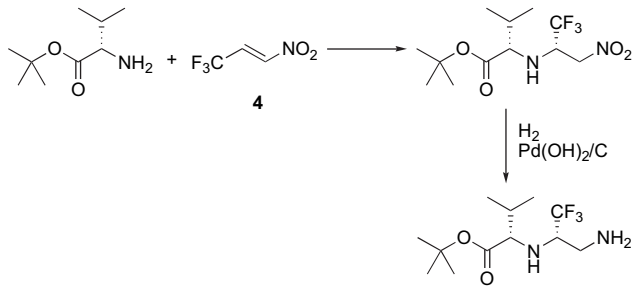


Scheme 4.

Katagiri et al. described the synthesis of optically active *N*,*N*′-substituted 1,2-diamino-3,3,3-trifluoropropanes **2** starting from optically pure 2,3-epoxy-1,1,1-trifluoropropane (Scheme 2).[7] In 2003, Uneyama's group developed an alternate strategy involving *N*-tosylaziridines (Scheme 3).[8] That has to be paralleled with a work by Soloshonok, who described aza-aldol reactions of chiral Ni(II) complex of glycine with imines (Scheme 4).[9] Prakash and Mandal developed a different route to access trifluoromethyl vicinal ethylenediamine involving nucleophilic trifluoromethylation of optically active (*R*)-*N*-*tert*-butanesulfinimines (Scheme 5).[10] Last, Zanda et al. described the diastereoselective addition of α-amino esters to 3,3,3-trifluoro-1-nitropropene (Scheme 6).[11] The diastereoselectivity observed by Zanda is in the range 23–84% depending on experimental conditions.



Scheme 5.



Scheme 6.

To the best of our knowledge, the literature do not disclose any other report on the synthesis, either stereoselective or not, of 1,2-diamino-2-perfluoroalkyl compounds. Herein we report our results concerning the stereoselective synthesis of 1,2-diamino-3,3,3-trifluoropropane **1** by Michael addition of amino compounds on prochiral *trans*-3,3,3-trifluoro-1-nitropropene **4**.

2. Results and discussion

The use of nitroalkenes as Michael acceptors has received much attention due to the number of efficient methods for converting nitro groups into amines, carbonyls, etc.[12] Aza-Michael reactions somewhat remained in the background as β-aminonitroalkanes are reported as unstable compounds.[13,14] Nevertheless, some remarkable results have been obtained concerning the addition of achiral, prochiral, or chiral nitrogen nucleophiles to either achiral, prochiral, or chiral nitroalkenes. Restricting our analysis to those diastereocontrolled addition reactions we can only find some 15 examples.[15–28] *trans*-3,3,3-Trifluoro-1-nitropropene **4** is a highly reactive Michael acceptor and is regioselectively attacked at the C2 position (Fig. 1).[29] To the best of our knowledge, the only aza-Michael reactions with **4** reported so far in the literature concern pyrazole **5** and triazoles **6**, adducts being obtained as pairs of enantiomers,[30] and α-amino esters as reported by Zanda et al.[11]

Intrigued by the diastereoselective potential of the aza-Michael reaction with 2-perfluoroalkyl-1-nitroalkenes we investigated the addition of a series of various chiral nitrogen

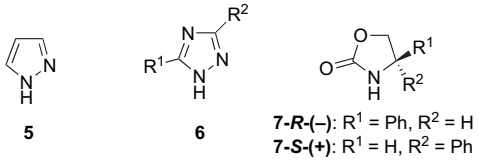
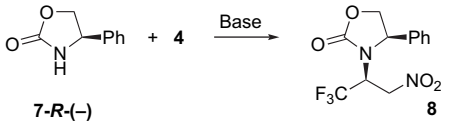


Figure 1.

nucleophiles to **4** to set up an access to enantiopure 1,2-diamino-2-perfluoroalkyl compounds.[31] Remarkable results were obtained with 4-phenyl-2-oxazolidinone **7** that is commercially available as both *R*-(−) and *S*-(+) isomers (Scheme 7). We studied the scope and the diastereoselectivity of the reaction as a function of experimental conditions such as temperature, base used for nitrogen deprotonation (or addition promoter), or solvent composition (Table 1).



Scheme 7.

The conjugate addition of 4-phenyl-2-oxazolidinone lithium or potassium salt to *trans*-3,3,3-trifluoro-1-nitropropene **4** proceeds smoothly and gets to completion within 15–30 min at −78 °C. Higher yields were invariably obtained using *n*-butyllithium as a base instead of potassium *tert*-butoxide. That is likely related to the size of the alkaline counter-ion, which is consistent with the intermediate result obtained with sodium hydride (Entry 14). Indeed *trans*-3,3,3-trifluoro-1-nitropropene **4** is unstable under basic conditions even at low temperature. Consequently the quicker the anion from **7** adds to the nitroalkene precluding its degradation, the better. That is equally consistent with the lower yield obtained when no phase transfer catalyst is used (Entry 3, 42% yield after 30 min). Due to the higher solubility of *n*-butyllithium in the reaction mixture, lack of 18-crown-6 in that case does not have drastic effects on conversion and yield (Entry 11). Alternative addition conditions have been tested. In the conditions described by Rawal et al., for the addition of oxazolidinones to 3-butyn-2-one (*N*-methylmorpholine, NMM)[32] no reaction occurs (Entry 15). Bis(acetonitrile)palladium(II) chloride has been recently described to promote the intramolecular addition of oxazolidinones to double bonds in a high yield.[33] However, in the conditions described by Hirai et al. 4-phenyl-2-oxazolidinone does not add to **4** and is integrally recovered after work up of the reaction mixture (Entry 16). The same negative results are obtained using potassium fluoride on alumina as described by Blass et al. for the addition of oxazolidinone to a series of various electrophiles.[34]

In all the experiments described herein a major diastereomer formed as expected from earlier results obtained with non-fluorinated nitroalkenes.[21] As fluorinated substituents may modify the stereochemical issue of diastereoselective reactions,[2] we were bent on determining the absolute configuration of the reaction adduct. A single-crystal X-ray analysis of compound **8** derived from (*R*)-(−)-4-phenyl-2-oxazolidinone showed that the chiral center that is created has an *S* absolute configuration (Fig. 2). That result is in agreement with those in the non-fluorinated series. The high level of asymmetric induction can be explained by a metal-chelated eight-membered transition state model (Fig. 3). Thus transition state TS-*re* suffers from steric repulsion between phenyl and trifluoromethyl groups, which does not exist in TS-*si*. Quite surprisingly the metal cation reveals extremely important for the diastereoselectivity of the reaction. While K^+

Table 1. Conjugate addition of *R*-(−)-4-phenyl-2-oxazolidinone **7** on *trans*-3,3,3-trifluoro-1-nitropropene **4**

Entry[a]	Compound **7**	*T* (°C)	Base	Conversion[b] (%)	Yield[c] (%)	de[d] (%)
1	*R*-(−)	−100	*t*-BuOK	66	55	64
2	*R*-(−)	−78	*t*-BuOK	68	54	58
3[e]	*R*-(−)	−78	*t*-BuOK	64	42	56
4	*R*-(−)	−40	*t*-BuOK	65	45	52
5	*R*-(−)	+25	*t*-BuOK	44	28	50
6	*R*-(−)	+50	*t*-BuOK	28	8	50
7[f]	*R*-(−)	−78	*t*-BuOK	60	48	50
8	*R*-(−)	−100	*n*-BuLi	80	74	92
9	*R*-(−)	−78	*n*-BuLi	100	83	92
10[g]	*R*-(−)	−78	*n*-BuLi	100	91	92
11[e]	*R*-(−)	−78	*n*-BuLi	100	83	92
12	*R*-(−)	−30	*n*-BuLi	100	85	86
13[h]	*R*-(−)	−78	*n*-BuLi	100	84	92
14[e,i]	*R*-(−)	−78	NaH	71	54	70
15[j]	*R*-(−)	+25	NMM	0	—	—
16[k]	*R*-(−)	+25	$PdCl_2(MeCN)_2$	0	—	—
17[l]	*R*-(−)	+25	KF/Al_2O_3	0	—	—
18[e]	*R*-(−)	−78	*t*-BuOLi	100	86	92
19	*R*-(−)	−78	PhMgCl	32	0	—
20	*S*-(+)	−78	*n*-BuLi	100	86	92

[a] Unless otherwise stated, stoichiometric amounts of **4**, **7**, and 18-crown-6 were allowed to react in THF for 15 min before addition of aqueous ammonium chloride and standard work up.
[b] Conversion of oxazolidinone **7**, evaluated by ^1H NMR spectroscopy.
[c] Based on isolated diastereomerically pure **8**.
[d] Evaluated by ^1H and ^{19}F NMR spectroscopies in the crude reaction mixture.
[e] No 18-crown-6 was used and reaction time was extended to 30 min.
[f] The reaction was carried out in DMF.
[g] Nitroalkene **4** (1.5 equiv) was used.
[h] The reaction was carried out in diethyl ether.
[i] Anion was prepared for 1 h at 50 °C.
[j] Experimental conditions are as described elsewhere.[32]
[k] Experimental conditions are as described elsewhere.[33]
[l] Experimental conditions are as described elsewhere.[34]

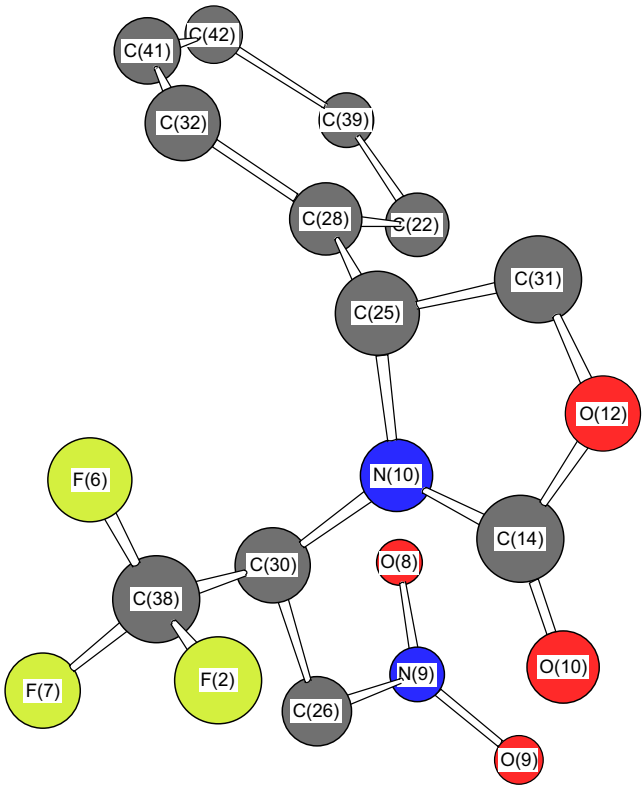


Figure 2. Structure of compound **8** resulting from the conjugate addition of **7**-*R*-(−) on **4** as determined by X-ray crystal analysis.

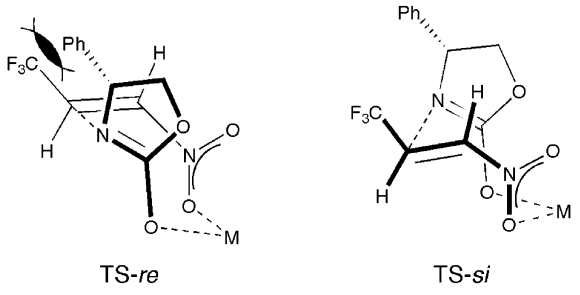
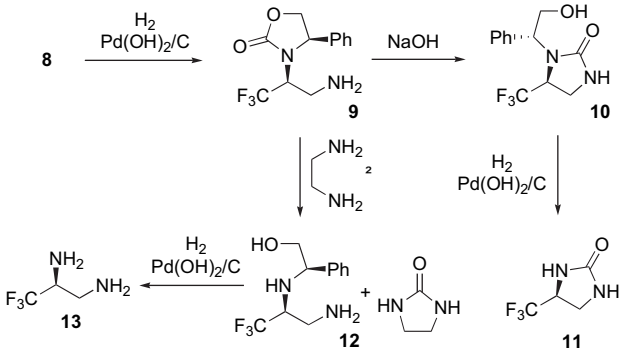


Figure 3.

yields medium diastereomeric excess (58% de, Entry 2), Na^+ and especially Li^+ give much better results (70% de and 92% de, respectively; Entry14 and Entries 8–11, 13, respectively). An additional experiment carried out with lithium *tert*-butoxide also gave 92% de indicating that the higher diastereoselectivity presumably results from a better fit between the geometry of the eight-membered ring transition state and the cation size (Entry 18). Diastereomeric excess obtained with potassium *tert*-butoxide is roughly the same when the reaction is carried out at +50 or −40 °C (50–52% de, Entries 4–6). A slight improvement, however, is observed at lower temperature and at −100 °C, 68% de is obtained (Entry 1). We tried to carry out the reaction at a temperature below −100 °C using a pentane/THF mixture. In that case, however, oxazolidine **7** proves only poorly soluble and does not allow synthetically useful conversion.

The transformation of **8** into 1,2-diamino-3,3,3-trifluoropropane **13** using the procedure described for non-fluorinated analogue compounds[21] revealed troublesome and inefficient (Scheme 8). Indeed catalytic reduction of the nitro group in **8** followed by a treatment of **9** with lithium in ammonia or sodium hydroxide did not afford diamine **13** as expected from results in the non-fluorinated series. Instead was obtained imidazolidone **10** that was then debenzylated to afford 4-trifluoromethyl-2-imidazolidone **11**. Further attempts to hydrolyze **11** for getting 1,2-diamino-3,3,3-trifluoropropane **13** invariably failed and complex mixtures of polar compounds were obtained that could not be separated even after treatment with acetyl chloride. To prevent the intramolecular rearrangement of aminocarbamate **9** into hydroxyurea **10**, the former was refluxed with ethylene diamine. We were then able to obtain diamine **12** nearly quantitatively together with 2-imidazolidone. Compound **12** was submitted to hydrogenolysis and optically pure *S*-(−)-1,2-diamino-3,3,3-trifluoropropane **13** was obtained. Debenzylation of **12**, however, proved difficult and despite many efforts for optimizing the experimental conditions (varying the nature and amount of catalyst used, hydrogen pressure, hydrogen source, temperature, solvent, and pH), compound **13** was never obtained in a yield better than 51%. About 40–45% of starting material was recovered unchanged and could be engaged in another hydrogenolysis cycle. Another debenzylation procedure using ammonium persulfate[35] proved inefficient to form compound **13**.



Scheme 8.

3. Conclusion

We have described the first diastereoselective synthesis of 1,2-diamino-3,3,3-trifluoropropane **13**. The title compound is prepared in four steps starting from readily available optically pure 4-phenyl-2-oxazolidinone **7** and *trans*-3,3,3-trifluoro-1-nitropropene **4**. The synthetic route is versatile and allows several intermediate function installations, especially on compounds **9** and **12**. Consequently unambiguous derivatization of one amino group or the other can be easily achieved and makes these compounds valuable intermediates for the elaboration of chiral non-racemic sophisticated fluorinated compounds.

4. Experimental

4.1. General procedure

^1H, ^{13}C, and ^{19}F NMR chemical shifts δ are reported in parts per million relative to their standard reference (^1H: $CHCl_3$ at

7.27 ppm, HDO at 4.63 ppm, CD_2HOD at 3.31 ppm; ^{13}C: $CDCl_3$ at 77.0 ppm, CD_3OD at 49.0 ppm; ^{19}F: $CFCl_3$ external at 0.00 ppm). IR spectra were recorded in wave numbers (cm^{-1}). Mass spectra (MS) and high-resolution mass spectra (HRMS) were recorded at chemical ionization (CI) or in the electro spray (ESI) mode. Mass data are reported in mass units (*m/z*). Abbreviations: s, singlet; d, doublet; t, triplet; q, quadruplet; m, multiplet; b, broad. *trans*-3,3,3-Trifluoro-1-nitropropene was prepared according to the literature.[36]

4.1.1. Synthesis of (−)-3-[2-(*S*)-(1-nitro-3,3,3-trifluoropropyl)]-[4-(*R*)-phenyl]-oxazolidin-2-one 8. A 1.6 M solution of *n*-butyllithium in hexane (370 μL, 0.61 mmol) is added dropwise to (*R*)-4-phenyloxazolidin-2-one (100 mg, 0.61 mmol) in anhydrous THF (5 mL) at −78 °C. Deprotonation is allowed to occur for 1 h before *trans*-3,3,3-trifluoro-1-nitropropene **4** (112 mg, 0.79 mmol) in THF (2 mL) is slowly added. The reaction mixture is stirred for 30 min at −78 °C, saturated aqueous NH_4Cl (3 mL) is added, and the temperature is allowed to rise to room temperature. The mixture is extracted with ether. The organic layer is washed with water, brine, dried over Na_2SO_4, and reduced under vacuum. The crude residue is purified by chromatography over silica gel (hexane/ethyl acetate 7:3) to yield **8** (169 mg, 91%) as a white solid. TLC R_f 0.5 (hexane/ethyl acetate 7:3). mp 108 °C. ^1H NMR ($CDCl_3$, 200 MHz) δ 7.57–7.31 (m, 5H); 5.49 (dd, J=8.6, 14.4 Hz, 1H); 4.99 (t, J=8.3 Hz, 1H); 4.78 (dd, J=4.7, 14.4 Hz, 1H); 4.73 (t, J=8.5 Hz, 1H); 4.40 (m, 1H); 4.29 (t, J=7.2 Hz, 1H). ^{13}C NMR ($CDCl_3$, 50 MHz) δ 156.9; 135.1; 130.7; 130.1; 128.3; 124.2 (q, J=284.0 Hz); 71.0; 70.1; 61.8; 53.8 (q, J=31.9 Hz). ^{19}F NMR ($CDCl_3$, 188 MHz) δ −71.2. IR (KBr) ν 2924; 1766; 1567; 1416; 1378; 1252; 1184; 1138. MS (CI/NH_3) *m/z* 322 $[M+NH_4]^+$; 339 $[M+NH_3+NH_4]^+$; 626 $[2M+NH_4]^+$. HRMS (ESI) *m/z* calcd for $C_{12}H_{11}F_3N_2NaO_4$ 327.0569, found 327.0574. $[\alpha]_D^{20}$ −61 (*c* 0.88, $CHCl_3$).

4.1.2. Synthesis of (−)-3-[2-(*S*)-(1-amino-3,3,3-trifluoropropyl)]-[4-(*R*)-phenyl]-oxazolidin-2-one 9. Compound **8** (570 mg, 1.88 mmol) and palladium hydroxide 20% (53 mg) in dry methanol (20 mL) are vigorously stirred under hydrogen pressure (30 bar) for 14 h at room temperature. The catalyst is removed by filtration over a Celite pad and washed with methanol. The filtrate is reduced in vacuo and the residue is dried in the presence of P_2O_5 to yield compound **9** (458 mg, 88%) as a colorless oil. ^1H NMR ($CDCl_3$, 300 MHz) δ 7.41–7.27 (m, 5H); 4.98 (dd, J=7.3, 8.9 Hz, 1H); 4.69 (t, J=8.9 Hz, 1H); 4.22 (dd, J=7.5, 8.7 Hz, 1H); 3.85 (m, 1H); 3.64 (s, 2H); 3.36 (dd, J=10.6, 13.7 Hz, 1H); 3.08 (dd, J=4.7, 13.4 Hz, 1H). ^{13}C NMR ($CDCl_3$, 75 MHz) δ 158.3; 137.4; 129.4; 129.0; 127.9; 124.6 (q, J=283.0 Hz); 70.9; 59.9; 58.2 (q, J=29.3 Hz); 36.8. ^{19}F NMR ($CDCl_3$, 188 MHz) δ −71.3. IR (film, CsI) ν 3369; 2923; 1755; 1534; 1416; 1363; 1245; 1177; 1131. MS (CI/NH_3) *m/z* 275 $[M+H]^+$; 549 $[2M+H]^+$. HRMS (ESI) *m/z* calcd for $C_{12}H_{14}F_3N_2O_2$ 275.1007, found 275.1012. $[\alpha]_D^{20}$ −40 (*c* 1.25, $CHCl_3$).

4.1.3. Synthesis of (−)-1-[2-hydroxy-1-(*R*)-phenylethyl]-5-(*S*)-trifluoromethylimidazolidin-2-one 10. Compound **9** (400 mg, 1.46 mmol) and sodium hydroxide (400 mg, 9.76 mmol) are stirred in refluxing methanol (8 mL) for 2 h. The reaction mixture is neutralized at 0 °C with HCl 3 M and extracted with ether. The organic layer is washed with brine, dried over $MgSO_4$, and reduced in vacuo to yield imidazolidone **10** (241 mg, 60%) as a slightly yellow oil. TLC R_f 0.65 (AcOEt). ^1H NMR ($CDCl_3$, 300 MHz) δ 7.41–7.27 (m, 5H); 6.30 (s, 1H); 4.63 (dd, J=3.7, 8.1 Hz, 1H); 4.27 (dd, J=8.1, 12.5 Hz, 1H); 4.04 (dd, J=3.7, 12.5 Hz, 1H); 3.92 (m, 1H); 3.60 (t, J=10.0 Hz, 1H); 3.50 (dd, J=3.7, 10.0 Hz, 1H). ^{13}C NMR ($CDCl_3$, 75 MHz) δ 163.3; 137.7; 129.3; 128.6; 127.6; 125.3 (q, J=281.2 Hz); 64.3; 63.6; 57.3 (q, J=31.8 Hz); 39.4. ^{19}F NMR ($CDCl_3$, 188 MHz) δ −76.3. IR (film, CsI) ν 3317; 2924; 1706; 1497; 1451; 1392; 1280; 1172; 1143. MS (CI/NH_3) *m/z* 275 $[M+H]^+$; 292 $[M+NH_4]^+$. HRMS (ESI) *m/z* calcd for $C_{12}H_{13}F_3N_2NaO_2$ 297.0821, found 297.0836. $[\alpha]_D^{20}$ −10 (*c* 7.5, $CHCl_3$).

4.1.4. Synthesis of (+)-4-(*S*)-trifluoromethylimidazolidin-2-one 11. Compound **10** (100 mg, 0.36 mmol) and palladium hydroxide 20% (100 mg) in dry methanol (8 mL) are vigorously stirred under hydrogen pressure (60 bar) for 46 h at room temperature. The catalyst is removed by filtration over a Celite pad and washed with methanol. The filtrate is reduced in vacuo and the residue is purified by silica gel chromatography (AcOEt/MeOH 9:1) to yield compound **11** (11 mg, 21%) as a white powder. TLC R_f 0.45 (AcOEt/MeOH 9:1). ^1H NMR (CD_3OD, 200 MHz) δ 4.40 (m, 1H); 3.79 (t, J=10.0 Hz, 1H); 3.55 (dd, J=4.6, 10.0 Hz, 1H). ^{13}C NMR (CD_3OD, 75 MHz) δ 165.8; 126.8 (q, J=278.0 Hz); 54.9 (q, J=32.6 Hz); 41.7. ^{19}F NMR (CD_3OD, 188 MHz) δ −81.8. IR (KBr) ν 3233; 1724; 1494; 1457; 1273; 1176; 1143. MS (CI/NH_3) *m/z* 172 $[M+NH_4]^+$; 189 $[M+NH_3+NH_4]^+$. HRMS (ESI) *m/z* calcd for $C_4H_5F_3N_2NaO$ 177.0252, found 177.0278. $[\alpha]_D^{20}$ +5 (*c* 0.83, MeOH).

4.1.5. Synthesis of 2-(1-aminomethyl-2,2,2-trifluoroethylamino)-2-phenyl-ethanol 12. Oxazolidinone **9** (250 mg, 0.91 mmol) is stirred in refluxing freshly distilled ethylene diamine for 18 h. Ethylene diamine is removed under vacuum and the residue is dissolved in HCl 1 M (15 mL), and washed with ether. The pH of the aqueous phase is brought to 14 with NaOH 6 M, and the solution is washed with ether. The organic phase is then washed with brine and dried over $MgSO_4$ to yield compound **12** (169 mg, 75%) as a slightly yellow oil. ^1H NMR ($CDCl_3$, 200 MHz) δ 7.37–7.33 (m, 5H); 4.10 (dd, J=4.2, 8.8 Hz, 1H); 3.73 (dd, J=4.4, 10.8 Hz, 1H); 3.63 (dd, J=8.6, 10.8 Hz, 1H); 2.93 (m, 1H); 2.89 (dd, J=4.1, 13.9 Hz, 1H); 2.72 (dd, J =5.1, 13.0 Hz, 1H). ^{13}C NMR ($CDCl_3$, 50 MHz) δ 140.1; 129.1; 128.4; 128.0; 67.8; 63.6; 57.7 (q, J=25.6 Hz); 41.0. ^{19}F NMR ($CDCl_3$, 188 MHz) δ −73.6. IR (film, CsI) ν 3344; 2926; 1670; 1602; 1454; 1358; 1264; 1134; 1071. MS (CI/NH_3) *m/z* 249 $[M+H]^+$. HRMS (ESI) *m/z* calcd for $C_{11}H_{16}F_3N_2O$ 249.1209, found 249.215. $[\alpha]_D^{20}$ −20 (*c* 0.50, $CHCl_3$).

4.1.6. Synthesis of (+)-2-(*S*)-1,2-diamino-3,3,3-trifluoropropane 13. Compound **12** (1.20 g, 4.83 mmol) and palladium hydroxide 20% (0.60 g) in THF/methanol 1:1 (80 mL) are vigorously stirred under hydrogen pressure (60 bar) for 48 h at room temperature. The catalyst is removed by filtration over a Celite pad and washed with methanol. The filtrate is reduced in vacuo and the residue is purified by column chromatography ($CHCl_3$/MeOH/concd NH_4OH 12:4:1) to yield residual starting material (504 mg)

and compound **13** (316 mg, 88% based on recovered starting material) as a brown liquid. TLC R_f 0.6 ($CHCl_3$/MeOH/concd NH_4OH 12:4:1). ^1H NMR ($CDCl_3$, 200 MHz) δ 3.39 (m, 1H); 3.16 (dd, J=3.7, 12.8 Hz, 1H); 2.83 (dd, J=9.5, 12.9 Hz, 1H). ^{13}C NMR ($CDCl_3$, 50 MHz) δ 126.3 (q, J=280.0 Hz); 54.8 (q, J=28.6 Hz); 40.6. ^{19}F NMR ($CDCl_3$, 188 MHz) δ −78.3. IR (film, CsI) ν 3373; 1558; 1411; 1269; 1161; 1016. MS (CI/NH_3) m/z 129 $[M+H]^+$; 146 $[M+NH_4]^+$. HRMS (ESI) m/z calcd for $C_3H_8F_3N_2$ 129.0640, found 129.0640. $[\alpha]_D^{20}$ +4 (c 6.00, $CDCl_3$).

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Supplementary data

Supplementary data associated with this article can be found in the online version, at doi:10.1016/j.tet.2006.06.013.

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