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Synthesis and stereodirected *N*-halogenation of *trans*-3-trifluoromethyl-2-methoxycarbonylaziridine

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Abstract

N-Fluorination of *trans*-3-trifluoromethyl-2-methoxycarbonylaziridine (**6**) with elemental fluorine (F_2/NaF, freon 113, at −5°C), stereoselectively affords the *trans*-*N*-fluoro derivative (F–N relative to $COOCH_3$), fluorination occurring from the side shielded by the CF_3 group. Chlorination of **6** and its amide **7** with Bu^{t}OCl (CH_2Cl_2 at −5 and −80°C) still affords the *trans*-*N*-chloroderivatives, though to a lesser extent (50% and 15%, respectively). The stereocontrol of the reaction seems to be due to the intramolecular H-bond.

Keywords: Asymmetric nitrogen; *N*-fluoroaziridine; *N*-chloroaziridine; Asymmetric halogenation

1. Introduction

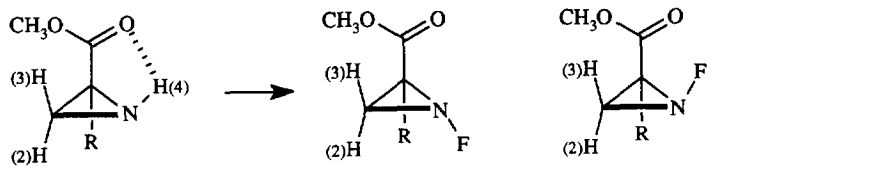
N-fluoroaziridinecarboxylates **2, 3** are subjects of interest because of their extraordinarily high barrier to nitrogen inversion (R=H) [1] and also because of the stereoselective nucleophilic substitution occurring at the acyl group *trans*-oriented with respect to the nitrogen substituent (R=$COOCH_3$) [2]. In a recent report, we described the stereoselective synthesis of these substrates, starting from the corresponding N–H aziridine **1** (Scheme 1), whose strong intramolecular H-bond was proved by NMR studies [3]; in particular, when R = H, we observed that the reaction of fluorination, carried out under conditions of H-bond retention (F_2/NaF, freon 113, at −5°C), afforded **2** alone, whereas, under conditions of H-bond breaking, both isomers **2** and **3** were obtained [1].

In this work, the first synthesis of *trans*-3-trifluoromethyl-2-methoxycarbonylaziridine **6** and its amide **7** is described and their *N*-halogenation reactions are investigated.

2. Results and discussion

2.1. Synthesis of aziridines

Aziridines **6** and **7** are synthesized by aminative cyclization of methyl 2,3-dibromo-4,4,4-trifluorobutanoate **4**, the latter being obtained by bromination of the commercially-available methyl 4,4,4-trifluorocrotonate (Scheme 2): if ammonia is



1 **2** **3** R = H, $COOCH_3$

Scheme 1.

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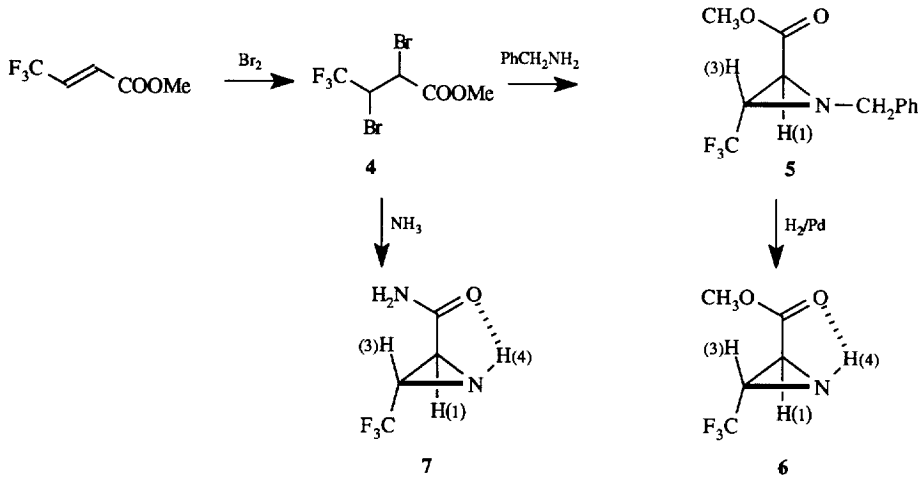
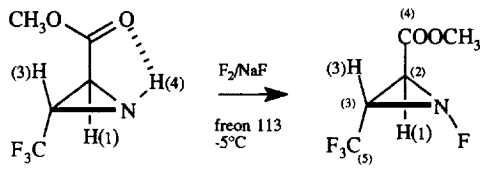


Scheme 2.



Scheme 3.

used, cyclization occurs together with the conversion of the methoxycarbonyl group into the carbamoyl one, to yield (46%) *trans*-3-trifluoromethyl-2-carbamoylaziridine **7**. *Trans*-3-trifluoromethyl-2-methoxycarbonylaziridine **6** can be obtained in good overall yield (70%) by cyclization of **4** with benzylamine in methanol, to afford **5**, and subsequent debenzylation of **5** with H_2 on Pd/C. The structures of **5, 6** and **7** are confirmed by physical and spectroscopic data. *Trans*-orientation of the substituents at 2,3-positions, as well as the presence of intramolecular H-bond in **6** and **7**, are established on the basis of the previously developed NMR criteria [3,4] as follows: $J_{H(3)H(4)}{}^{cis} > J_{H(1)H(4)}{}^{trans} > J_{H(1)H(3)}{}^{trans}$. Spin coupling constants observed for **6** and **7** are in good agreement with the above rule, i.e., $J_{H(3)H(4)}{}^{cis}$ (12.5 and 10.1 Hz) $> J_{H(1)H(4)}{}^{trans}$ (8.0 and 7.8 Hz), and the assignment of $J_{H(1)H(3)}{}^{trans}$ in **5** (2.4 Hz) and **6, 7** (2.3 Hz) is in close agreement with other related compounds [5].[2]

2.2. Fluorination of aziridine 6

Under condition of H-bond retention, aziridine **6** undergoes fluorination (Scheme 3) to afford *t*-1-fluoro-*t*-3-trifluoromethyl-*r*-2-methoxycarbonylaziridine[3] **8** in a single diastereoisomeric form, as revealed by ^1H, ^{13}C and ^{19}F NMR spectroscopy. *Trans*-orientation of the fluorine atom relative to the $COOCH_3$ group in **8** is unambiguously stated by the NMR spectra analysis: $J_{H(1)F}{}^{cis}$ (32.7 Hz) $> J_{H(3)F}{}^{trans}$ (18.9 Hz); $^1J_{CH(3)}$ (181.6 Hz) $> {}^1J_{CH(1)}$ (179.7 Hz); $^3J_{C(4)CNF}{}^{trans} = 7.5$ Hz ($^3J_{C(4)CNF}{}^{cis} = 8.6$–$8.7$ Hz for **3** (R = H, $COOCH_3$) [1,2]); $^4J_{FNCCF}{}^{cis} = 19.0$ Hz; ($^4J_{FNCCF}{}^{cis} = 23.1$; $^4J_{FNCCF}{}^{trans} = 2.2$ Hz for 1-fluoro-2,2-bis-trifluoromethyl-aziridine [2]). The higher ASIS (Aromatic Solvent Induced Shift) effect observed for proton H(3) by comparison with those recorded for H(1) (see) confirms the *trans*-relative configuration.

It follows from the above data that fluorination of aziridine **6** proceeds from the face of the heterocycle shielded by the CF_3 group; the ASIS effect indicates a higher steric hindrance for this face than for the other. In order to determine the degree of steric hindrance, we estimated the distance F···F between the fluorine atoms in NF and CF_3 in **8**: Dreiding models gave values of about 2 and 2.5 Å (for eclipsed and *gauche* conformations, respectively) whereas the through-space ^{19}F–^{19}F spin–spin coupling [6] model gives the value of 2.97 Å.

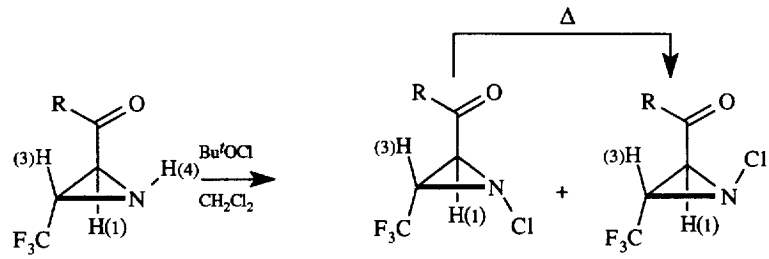
In contrast with the fluorination of aziridine **1** [1], attempts to change the direction of fluorination of **6** under conditions of H-bond breaking by the action of Et_3N failed. In fact, fluorination of **6** (F_2/N_2 in freon 113 with an equimolar quantity of Et_3N, 45 min, −10°C) resulted in an unresolvable mixture of unknown products (no signals of the desired compounds were observed in the NMR spectra of the crude mixture). It is assumed that, owing to the lower nucleophility of nitrogen in aziridine **6** with respect to **1**, Et_3N is predominantly fluorinated and **6** decomposes with the evolution of HF. Attempts to determine the nitrogen inversion barrier in **8** were also unsuccessful: the sample decomposed completely upon heating in toluene-d_8 (24 h at 100°C).

2.3. Chlorination of aziridines 6 and 7

Halogenation of **6** with the bulky chlorinating agent *t*-butyl-hypochlorite (Bu^tOCl, Scheme 4) was therefore inves-

[2] For example, in 1-methyl-2-benzoyl-3-trifluoromethylaziridine: $J_{H(1)H(2)}{}^{cis}$ (6.0 Hz) $> J_{H(1)H(3)}{}^{trans}$ (2.7 Hz).

[3] Nomenclature of compounds **8–10** is given following indications reported in: E.L. Eliel, S.H. Wilen, Stereochemistry of Organic Compounds, Wiley, Chichester, 1994, pp. 665–666.



6 (R = OCH_3)
7 (R = NH_2)

9a (R = OCH_3)
10a (R = NH_2)

9b (R = OCH_3)
10b (R = NH_2)

Scheme 4.

tigated. With this reagent, a partial breaking of the intramolecular H-bond is to be expected, owing to the formation of *t*-butyl alcohol as reaction product. Chlorination performed at low temperature ($-80°C$) gave *t*- and *c*-1-chloro-*t*-3-trifluoromethyl-*r*-2-methoxycarbonylaziridine (**9a, 9b**) as mixture of isomers in a 1:1 ratio, which, on standing at room temperature (30 min at 24°C), equilibrated at a ratio of 1:14.

The same reaction performed on compound **7** (Scheme 4) at $-5°C$ resulted in the predominant formation of *t*-1-chloro-*t*-3-trifluoromethyl-*r*-2-carbamoylaziridine (**10a**; TLC analysis, ^1H NMR of crude product), which, on standing at room temperature (12 h), converted into **10b** to afford the mixture of **10a:10b** in a 1:5.7 ratio; crystallization of this mixture from methylene chloride afforded pure *c*-1-chloro-*t*-3-trifluoromethyl-*r*-2-carbamoylaziridine **10b**, according to an asymmetric transformation induced by crystallization.

The structures and relative configurations of isomers **9** and **10** are confirmed by spectroscopic data. In particular, as follows from the value of $^1J_{CH(1)} > {}^1J_{CH(3)}$ in isomers **9b** and **10b**, H(1) must be *cis* oriented with respect to the nitrogen lone pair [7]; conversely, in isomers **9a** and **10a**, showing $^1J_{CH(1)} < {}^1J_{CH(3)}$, the opposite configuration must be attributed. This attribution of configuration to aziridine **9b** is in agreement with the value of the ASIS effect (see Table 1); spontaneous epimerization of **9a** into **9b** and **10a** into **10b** at room temperature also confirms this configuration. Furthermore, the values of inversion barriers in the known derivatives of 1-chloro-aziridinecarboxylic acids are not high ($\Delta G^{\#}$ 24–25.5 kcal mol^{-1} [8]) and have to decrease under the influence of the bulky substituent CF_3 as is actually observed for **9a** and **10b** Table 1.

Table 1
ASIS effect for compounds **6, 8** and **9b**

Compound	$\Delta\delta = (\delta_{CDCl3} - \delta_{toluene\text{-}d8})$, ppm		
	H(1)	H(3)	CH_3O
6	0.31	0.56	0.66
8	0.44	0.57	0.82
9a	0.55	0.32	0.80

3. Conclusion

Trans-3-trifluoromethyl-2-methoxycarbonylaziridine **6** and its amide **7** are synthesized in good chemical yields, and the *trans*-relative configurations are well established. Fluorination of **6**, under conditions of intramolecular H-bond retention, proceeds with high diastereoselection from the face of the heterocycle bearing the CF_3 group, and the *N*-fluoro derivative **8** is isolated in a single diastereoisomeric form. Chlorination of **6** and **7**, carried out under conditions of partial H-bond breaking, affords the corresponding *N*-chloroderivatives as mixture of isomers. The stereoselection of the halogenation seems to be due to the intramolecular H-bond, and to be independent of the steric demand of CF_3.

4. Experimental

NMR spectra were recorded on Bruker WM-400, AM-300, AC-200, and DPX-200 spectrometers. Chemical shifts are reported in δ values from TMS as internal standard (^1H, ^{13}C), CF_3CO_2H (^{19}F) and $MeNO_2$ (^{15}N) as external standards (s, singlet, d, doublet, m, multiplet, t, triplet, b, broad signal); coupling constants (J) are given in Hz. Spin coupling constants $^1J_{CH}$ for **10** were measured by the HMQC technique, 1D-version [7]. ^{15}N NMR spectra were measured for the natural abundance of ^{15}N; spin coupling constant $^2J_{15NH(1)}$ was determined by spin polarization transfer (SPT) from proton H(1) to ^{15}N nucleus. GLC analyses were performed on a Hewlett-Packard 5890A gas chromatograph, carrier helium gas; conversions were evaluated on DB-1 column (30 m × 0.53 mm i.d. and 5 μm film phase) from J & W Scientific. Mass spectra were determined on a Hewlett-Packard 5970 mass selective detector (EI, 70 eV). Chromatographic purification of the compounds was performed on silica gel (Ø 0.05–0.2 mm). Methyl-4,4,4-trifluoro-*trans*-2-butenoate was purchased from Fluorochem. Elemental analyses were performed with a Carlo Erba Elemental Analyzer.

4.1. Methyl 2,3-dibromo-4,4,4-trifluorobutanoate (4)

2.5 g (16.2 mmol) of methyl 4,4,4-trifluoro-*trans*-2-butenoate and 0.84 ml (16.4 mmol) of bromine, in 70 ml of carbon

tetrachloride were gently refluxed until the color completely disappeared (3 h). Thereafter, the solvent was removed in vacuo and the oily residue (5.1 g) distilled under reduced pressure to give 4.6 g (90% yield) of **4** as a colourless oil; b.p. 58–60°C (2 mm Hg). Anal. Found: C, 19.2; H, 1.7. Calcd. for $C_5H_5Br_2F_3O_2$: C, 19.1; H, 1.6%. ^{1}H NMR ($CDCl_3$): 3.90 (s, 3H, MeO); 4.58 (d, 1H, *J* 10.6); 4.72 (dq, 1H, *J* 10.6, 6.1); Mass spectrum, *m/z* (rel. intens. %): 316 (1), and 314 (2), 316 (1) [M^+], 283 (2), 257 (7), 255 (10), 253 (7), 235 (17), 233 (17), 191 (9), 189 (9), 176 (13), 155 (3), 123 (20), 95 (19), 75 (5), 69 (34), 59 (100).

4.2. Trans-1-benzyl-3-trifluoromethyl-2-methoxycarbonylaziridine (5)

4.6 g (14.6 mmol) of **4** in methanol (30 ml) was slowly added to a cooled solution (−5°C) of benzylamine (6.4 ml, 58.4 mmol) in methanol (70 ml) with vigorous stirring. The cooling bath was then removed and the mixture allowed to react for 18 h. The solvent was removed under reduced pressure and 50 ml of diethyl ether was added to the residue; the precipitate (benzylammonium hydrobromide) was filtered off, the solvent removed and the crude product purified by column chromatography (hexane/ethyl acetate as eluent) to afford 2.95 g of aziridine **5** (78% yield) recovered as a colourless oil; b.p. 74–76°C (0.4 mm Hg). Anal. Found: C, 55.56; H, 4.67; N, 5.35. Calcd. for $C_{12}H_{12}NO_2F_3$: C, 55.60; H, 4.64; N, 5.40%. ^{1}H NMR ($CDCl_3$): 3.00 (dq, 1H, H(3), *J* 2.4, 5.0); 3.04 (d, 1H, H(1), *J* 2.4); 3.76 (s, 3H, MeO); 4.05 (m, 2H, CH_2N, AB spectrum, $\Delta\nu$ 32.0, *J* 13.6); 7.33–7.39 (m, 5H, Ph); *m/z* (rel. intens. %): 259 [M^+] (4), 258 (16), 244 (15), 228 (8), 200 (27), 190 (91), 180 (9), 158 (80), 130 (24), 123 (24), 105 (55), 104 (82), 91 (100), 77 (17), 69 (7), 65 (44).

4.3. Trans-3-trifluoromethyl-2-methoxycarbonylaziridine (6)

A solution of **5** (2.05 g, 7.9 mmol) in methanol (15 ml) and acetic acid (3.5 ml) was stirred at room temperature with Pd 10% on carbon (100 mg) under 1 atm of hydrogen until absorption of the required volume (190 ml in 1 h). The catalyst was then removed by filtration and the solution concentrated in vacuo. The residue was dissolved in diethyl ether (50 ml) and washed with saturated $NaHCO_3$ in water and dried over Na_2SO_4. After filtration and concentration, the residue was purified from the remaining toluene by column chromatography (petroleum ether/diethyl ether as eluent). The fractions containing aziridine were collected and concentrated; after distillation 1.25 g of pure **6** (90% yield) was obtained as a colourless oil; b.p. 85–87°C (35 mm Hg). ^{1}H NMR ($CDCl_3$): 1.75 (br, 1H, H(4)); 2.86 (dd, 1H, H(1), *J* 8.0, 2.3); 2.91 (ddq, 1H, H_3, *J* 12.5, 4.9, 2.3); 3.86 (s, 3H, MeO); (toluene-d_8): 1.28 (br, 1H, H(4)); 2.35 (ddq, 1H, H(3), *J* 10.1, 5.0, 2.2); 2.55 (dd, 1H, H(1), *J* 8.0, 2.1); 3.20 (s, 3H, MeO); *m/z*: 170 (1) [M+1]$^+$, 169 (1) [M^+], 154 (2), 137 (16), 118 (4), 110 (42), 109 (100), 100 (21), 90 (50), 82 (9), 69 (16), 59 (16).

4.4. Trans-3-trifluoromethyl-2-carbamoylaziridine (7)

4.0 g (12.7 mmol) of **4** in methanol (10 ml) was slowly added to a cooled solution (0°C) of aqueous ammonia (30%, 20 ml) with vigorous stirring. The cooling bath was then removed and the mixture allowed to react for 18 h. The solvent was removed under reduced pressure and 80 ml of dichloromethane were added to the residue; the precipitate (ammonium bromide) was filtered off, the solvent removed and the crude product is purified by column chromatography (dichloromethane/ethyl acetate/methanol, 80/20/1, as eluent), to afford 0.91 g of aziridine **7** (46% yield), recovered as white crystals; m.p. 101–102°C. Anal. Found: C, 31.15; H, 3.30; N, 18.15. Calcd. for $C_4H_5N_2OF_3$: C, 31.18; H, 3.27; N, 18.18%. ^{1}H NMR ($CDCl_3$): 1.86 (br, 1H, H(4)); 2.64 (dd, 1H, H(1), *J* 7.8, 2.3); 2.83 (ddq, 1H, H(3), *J* 10.1, 5.1, 2.3); 5.90 (br, 2H, NH_2); *m/z*: 154 (1) [M^+], 138 (76), 137 (20), 118 (5), 110 (60), 109 (75), 90 (100), 85 (53), 69 (26), 63 (9), 59 (14), 58 (15), 51 (6).

4.5. t-1-Fluoro-t-3-trifluoromethyl-r-2-methoxycarbonylaziridine (8)

The mixture of F_2/N_2 (14% vol. of F_2) was passed through the mixture of aziridine **6** (1 g, 5.9mmol) and NaF (2.5 g, 59.5 mmol) in freon 113 (30 ml), in a stream of argon, with cooling (−5°C) and stirring (2 h). The resulting precipitate was filtered off and washed with dichloromethane. The solvents were evaporated and the residue distilled to give 0.88 g (75.5% yield) of **8** as a colourless thin fluid turning yellowish in air; b.p. 65°C (25 Torr). Anal. Found: C, 32.19; H, 2.73, N, 7.35. Calcd. for $C_5H_5NO_2F_4$: C, 32.10, H, 2.69; N, 7.48%.

^{1}H NMR ($CDCl_3$): 3.30 (ddq, 1H, H(3), *J* 18.9, 7.0, 6.1); 3.64 (dd, 1H, H(1), *J* 32.7, 7.0); 3.85 (s, 3H, MeO). ^{1}H NMR (toluene-d_8): 2.73 (ddq, 1H, H(3), *J* 18.9, 7.3, 6.0); 3.03 (s, 3H, MeO); 3.20 (dd, 1H, H(1), *J* 33.6, 7.3); ^{13}C NMR ($CDCl_3$): 44.77 (ddqd, C(2), ^1J 179.7, $^2J_{CNF}$ 6.0, $^3J_{CCCF}$ 2.6, $^2J_{CCCH}$ 1.5); 45.94 (dqdd, C(3), ^1J 181.6, $^2J_{CCF}$ 39.6, $^2J_{CNF}$ 5.5, $^2J_{CCH}$ 3.7); 53.05 (q, MeO, ^1J 148.8); 121.07 (qdd, CF_3, $^1J_{CF}$ 274.8, $^3J_{CCNF}$ 10.2, $^3J_{CCCH}$ 5.4); 164.3 (ddq, CO, $^3J_{CCNF}$ 7.5, $^2J_{CCH}$ $^3J_{COCH}$ 4.0). ^{19}F NMR ($CDCl_3$): 11.74 (ddq, FN, $^3J_{FNCH(1)}$ 32.7, $^3J_{FNCH(3)}$ $^4J_{FNCCF}$ 19.0); 14.2 (dd, CF_3, $^4J_{FCCNF}$ 19.0, $^3J_{FCCH}$ 6.1); *m/z*: 168 (12.4) [M–F]$^+$, 156 (10.5), 140 (4.8), 123 (6.9), 113 (100), 109 (26.9), 101 (9.4), 90 (15.2), 82 (7.3), 78 (11.5), 69 (30.1), 63 (19.2), 59 (72.0), 51 (15.5), 42 (4.9), 40 (5.8), 33 (4.1), 31 (5.2), 29 (8.0), 15 (68.5).

4.6. t- and c-1-Chloro-t-3-trifluoromethyl-r-2-methoxycarbonylaziridine (9a, 9b)

(a) *t*-Butylhypochlorite in CH_2Cl_2 (2.16 N, 1.61 ml) was added dropwise to a stirred solution of **6** (0.29 g, 1.72 mmol) in CH_2Cl_2 (20 ml), cooled at −5°C. After 5 min the solvent was evaporated and the residue chromatographed (light petroleum/diethyl ether, 7/3, as eluent) to give **9** as an oil (0.27 g, 79%), b.p. 38–40°C (1 Torr).

^{1}H NMR ($CDCl_3$): 3.35 (d, 1H, H(1), *J* 4.5); 3.51 (dq, 1H, H(3), *J* 4.5, 5.0); 3.93(s, 3H, MeO). ^{1}H NMR (C_6D_6): 2.80 (d, 1H, H(1), *J* 5.3); 3.13 (s, 3H, MeO); 3.19 (dq, 1H, H(3), *J* 5.3); ^{13}C NMR (C_6D_6): 44.93 (ddq, 2C, $^1J_{CH}$ 184.0, $^2J_{CH}$ 2.4, $^3J_{CF}$ 1.5); 48.64 (dqd, 3-C, $^1J_{CH}$ 179.4, $^2J_{CF}$ 40.5, $^2J_{CH}$ 3.0); 53.23 (q, MeO, $^1J_{CH}$ 148.3); 117.6 (qdd, CF_3, $^1J_{CF}$ 274.3, $^3J_{CH(1)}$ 3.1, $^2J_{CH(3)}$ 1.5); 163.14 (dq, CO, $^2J_{CCH(3)} = {}^3J_{COCH}$ 3.8). ^{19}F NMR spectrum (in C_6D_6) indicates the presence of **9** as a mixture of two invertomers. Major isomer **9b** (96%): 5.56 (d, CF_3, $^3J_{FCCH(3)}$ 5.3). Minor isomer **9a** (4%): 13.31 (d, CF_3, $^3J_{FCCH(3)}$ 6.4). ^{15}N NMR (C_6D_6): −320 (d, N-ring, $^2J_{NCH(1)}$ 12.0); *m/z*: 205 (1) and 203 (3) [M^+], 168 (13), 146 (3), 144 (9), 123 (6), 113 (100), 107 (28), 90 (24), 82 (9), 69 (23), 65 (15), 59 (45), 15 (15).

(b) The mixture of **9a** and **9b** was obtained in a quantitative yield in a 1:1 ratio (by ^{1}H and ^{19}F NMR) from 50 mg of **6** in 1 ml of CH_2Cl_2 under the action of 4-fold excess of Bu^{t}OCl at −80°C followed by evaporation at the same temperature in vacuo (1 Torr). For **9a**: ^{1}H NMR ($CDCl_3$): 3.20–3.36 (m, 2H, H(1) and H(3)); 3.82 (s, 3H, MeO). ^{13}C NMR (toluene-d_8): 46.9 (q, C(3), $^2J_{CF}$ 38.6); 47.4 (s, C(2)); 53.4 (s, MeO); 123.4 (q, CF_3, $^1J_{CF}$ 275.9); 166.6 (s, CO). After 0.5 h at 24°C, the ratio of **9a** to **9b** changed to 1:14 (by ^{19}F NMR).

4.7. t- and c-1-Chloro-t-3-trifluoromethyl-r-2-carbamoylaziridine (10)

t-Butylhypochlorite in dichloromethane (2.16 N, 0.95 ml) was added dropwise to a stirred solution of **7** (0.15 g, 0.97 mmol) in dichloromethane (25 ml), cooled at −5°C. After 30 min, the cooling bath was removed and the mixture allowed to react for 12 h until **7** had disappeared. Thereafter, the solvent was evaporated and the residue chromatographed (dichloromethane/ethyl acetate/methanol, 80/20/1, as eluent) to give 0.16 g (85% yield) of **10** as white crystals; m.p. 82–84°C. Anal. Found: C, 25.89; H, 2.17; N, 14.75. Calcd. for $C_4H_4F_3Cl$: C, 25.5; H, 2.1; N, 14.9%. The ^{1}H NMR spectrum indicates the presence of **10** as a mixture of two isomers; $^1J_{CH(1)}$ 181.7; $^1J_{CH(3)}$ 179.0. Major isomer **10b** (85%): 3.22 (d, 1H, H(1), *J* 4.6); 3.57 (qd, 1H, H(3), *J* 5.1, 4.6); 6.20 (br, 2H, NH_2). Minor isomer **10a** (15%): 3.13 (dq, 1H, H(3), *J* 4.6, 6.3); 3.31 (d, 1H, H(1), *J* 4.6); 5.8 (br, 2H, NH_2); $^1J_{CH(1)}$ 178.9; $^1J_{CH(3)}$ 182.1; *m/z* (%): 191 (0.2) and 189 (0.6) [M+1]$^+$, 190 (0.3) and 188 (0.9) [M^+], 173 (0.3), 171 (1), 154 (4), 153 (100), 134 (6), 110 (21), 109 (15), 98 (31), 90 (25), 82 (9), 69 (22), 60 (17), 59 (14). Crystallization of this mixture from methylene chloride afforded diastereoisomerically pure **10b** in nearly quantitative yield.

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