Synthesis of Trifluoromethylated Amines Using 1,1-Bis(dimethylamino)-2,2,2-trifluoroethane

Yuelian Xu and William R. Dolbier, Jr.*

Department of Chemistry, University of Florida, Gainesville, Florida 32611-7200

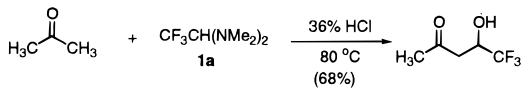
Received November 9, 1999

Lewis acid-catalyzed deamination of aminal, 1,1-bis(dimethylamino)-2,2,2-trifluoroethane, using ZnI_2 in ether, generates the 2,2,2-trifluoro-1,1-dimethylaminoethyl carbocation, which undergoes synthetically useful electrophilic reactions with alkynes, a variety of electron-rich alkenes, and TMS cyanide to form trifluoromethylated alkynylamines, homoallylic amines, α,β-unsaturated ketones, and cyanoamines in fair to good yields.

Compounds containing a trifluoromethyl group continue to be of great industrial interest,[1] and therefore, the development of new methods to incorporate trifluoromethyl (CF_3) groups into organic compounds remains an important area of study.[2] Among the many approaches used to make trifluoromethylated compounds,[3] trifluoroacetaldehyde, along with its derivatives, remains one of the most useful building blocks, and it has been used for the construction of functionalized trifluoromethylated compounds via reaction with a number of nucleophilic reagents.

Ordinarily, the generation of carbocations with an α-trifluoromethyl substituent is difficult because of the strong electron-withdrawing effect of a CF_3 group.[4,5] Recently, the groups of Fuchigami and Uneyama have reported the synthesis of trifluoroacetaldehyde *N*,*O*- and *O*,*S*-acetals, using electrochemical methodology.[6] These CF_3-substituted acetals could be used to generate, via Lewis acid catalysis, carbocation intermediates stabilized by their neighboring oxygen and nitrogen or sulfur atoms, and these intermediates could be effectively intercepted by various nucleophiles to make carbon−carbon bonds. Also, α-trifluoromethyl iminium trifluoroacetates were prepared from *N*-oxides of trifluoroethylamines.[7]

Recently, in a preliminary report, we demonstrated that 1,1-bis(dimethylamino)-2,2,2-trifluoroethane (**1a**) can function as a useful building block in condensation reactions with ketones.[8] Here, we wish to expand on that report, and present results on the general construction of carbon−carbon bonds using this readily available reagent. Useful synthetic methods have been developed for the reaction of 1,1-bis(dimethylamino)-2,2,2-trifluoroethane, under Lewis acid catalysis, with various electron-rich alkenes and alkynes, including terminal alkynes, 2-(trimethylsilyl)-1-phenylacetylene, trimethylsilyl (TMS) cyanide, allyltrimethylsilane, and propargyltrimethylsilane.



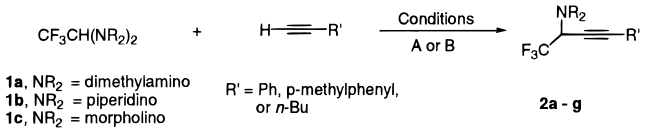
Results and Discussion

Reactions with Terminal Alkynes. Aminals have been widely used as convenient precursors of iminium ions, which are perhaps most importantly intermediates in the Mannich reaction.[9] A number of methods have been developed for the generation of such intermediates, the best known of which is Eschenmoser's salt, which can be formed conveniently in aprotic solvents from *N*,*N*,*N*′,*N*′-tetramethyldiaminomethane.[10−13]

Komissarov has reported that aminals derived from aromatic aldehydes can be condensed with phenylacetylene and Cu(I) halides in acetonitrile to give propargylamines in good yields.[14,15] Under similar conditions, as shown in Table 1 (condition A), the reaction of 1,1-bis(dialkylamino)-2,2,2-trifluoroethanes with arylacetylenes proceeded adequately, but considerably slower than the analogous reactions with nonfluorinated aminals. In particular, it was found that aliphatic alkynes, such as 1-hexyne were poor substrates for this reaction, requiring 4 days reaction to provide <50% conversion.

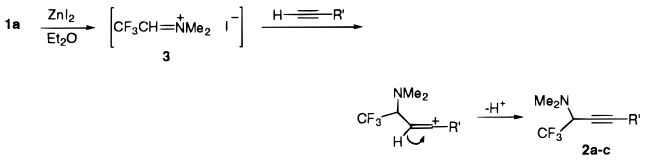
(1) Filler, R., Kobayashi, Y., Yagupolskii, L. M., Eds. *Organofluorine Compounds in Medicinal Chemistry and Biomedical Applications*; Elsevier: Amsterdam, 1993.
(2) McClinton, M. A.; McClinton, D. A. *Tetrahedron* **1992**, *48*, 6555.
(3) Percy, J. M. *Top. Curr. Chem.* **1997**, *193*, 131.
(4) Bonnet-Delpon, D.; Cambillau, C.; Charpentier-Morize, M.; Jacquot, R.; Mesureur, D.; Ourevitch, M. *J. Org. Chem.* **1988**, *53*, 754.
(5) Umemoto, T.; Gotoh, Y. *Bull. Chem. Soc. Jpn.* **1987**, *60*, 3823.
(6) (a) Fuchigami, T.; Nakagawa, Y.; Nonaka, T. *Tetrahedron Lett.* **1986**, *27*, 3869. (b) Fuchigami, T.; Yamamoto, K.; Nakagawa, Y. *J. Org. Chem.* **1991**, *56*, 137. (c) Fuchigami, T.; Nakagawa, Y.; Nonaka, T. *J. Org. Chem.* **1987**, *52*, 5491. (d) Fuchigami, T.; Ichikawa, S.; Kandeel, Z. E.; Konno, A.; Nonaka, T. *Heterocycles* **1990**, *31*, 415. (e) Fuchigami, T. *Top. Curr. Chem. 170*, 1. (f) Fuchigami, T.; Ichikawa, S. *J. Org. Chem.* **1994**, *59*, 607. (g) Uneyama, K.; Momota, M.; Hayashida, K.; Itoh, T. *J. Org. Chem.* **1990**, *55*, 5364. (h) Uneyama, K.; Momota, M. *Tetrahedron Lett.* **1989**, 2265.
(7) (a) Ates, C.; Janousek, Z.; Viehe, H. G. *Tetrahedron Lett.* **1993**, *34*, 5711. (b) Rover-Kever, M.; Vertommen, L.; Huys, F.; Merenyi, R.; Janousek, Z.; Viehe, H. G. *Angew. Chem., Int. Ed. Engl.* **1981**, *20*, 1023.
(8) Xu, Y.; Dolbier, W. R., Jr. *Tetrahedron Lett.* **1998**, *39*, 9151.
(9) Tramontini, M. *Synthesis* **1973**, *12*, 703.
(10) Schreiber, J.; Maag, H.; Hashimoto, N.; Eschenmoser, A. *Angew. Chem.* **1971**, *83*, 355.
(11) Cooper, M. S.; Fairhurst, R. A.; Heaney, H.; Papageorgiou, G.; Wilkins, R. F. *Tetrahedron* **1989**, *45*, 1155.
(12) de Solms, S. J. *J. Org. Chem.* **1976**, *41*, 2650.
(13) Heaney, H.; Papageorgiou, G.; Wilkins, R. F. *J. Chem. Soc., Chem. Commun.* **1988**, 1161.
(14) Komissarov, V. N.; Ukhin, L. Yu. *Zh. Org. Khim.* **1987**, *23*, 1326.
(15) Propargylamines have also been prepared directly by the reaction of Li acetylides with *N*-sulfonylimines: Masquelin, T.; Obrecht, D. *Synthesis* **1995**, 276.

10.1021/jo991750y CCC: $19.00
Published on Web 03/16/2000

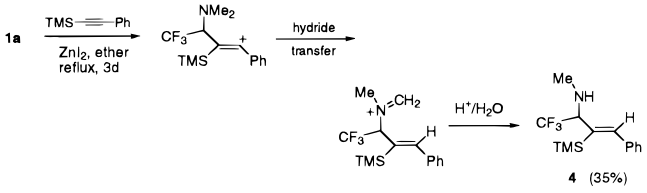


Lewis acids have been used to generate in situ CF_3-CH^+-X cations from trifluoroacetaldydyde *N*,*O*-acetals[6f] and *O*,*O*-acetals.[16] After unsuccessfully trying $SnCl_4$/1,2-dichloroethane, $TiCl_4/CH_2Cl_2$, and BF_3/ether to initiate similar reactions from aminal **1a**, it was found that use of ZnI_2 as Lewis acid in THF led to much improved results in reactions with the alkynes, as shown in Table 1 (condition B).

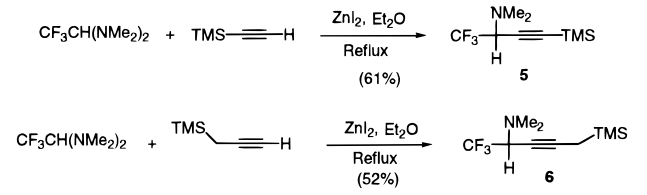
Presumably, the mechanism of this Lewis acid catalyzed reaction involves formation of the intermediate iminium cation **3**, followed by its addition to the alkyne and subsequent loss of a proton, as depicted below:



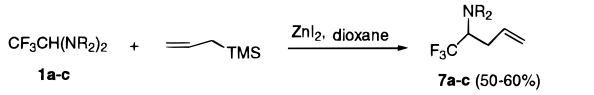
Although diphenylacetylene proved unreactive under these conditions, refluxing 1,1-bis(dimethylamino)-2,2,2-trifluoroethane (**1a**) with 1-phenyl-2-(trimethylsilyl)-acetylene in the presence of ZnI_2 for 3 days in ether led to formation of an unusual condensation product, **4**, in 35% yield, presumably via the hydride-transfer mechanism depicted below.



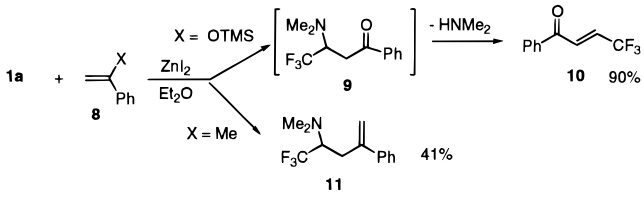
Looking at simpler TMS-substituted alkynes, both TMS acetylene and propargyl trimethylsilane reacted with **1a** under the same ZnI_2-catalyzed conditions to give the same type of terminal H-substitution products (**5** and **6**, respectively) as those in Table 1. That is, in each case the TMS groups are retained in the product. In the case of the propargyl TMS this was somewhat surprising since there is precedent for reaction of propargyl TMS with electrophiles leading to allene formation with loss of the TMS group.[17]



Reactions of Electron-Rich Alkenes. In contrast to the reaction of **1a** with propargyl TMS, the reactions of aminals **1a**−**c** with allyltrimethylsilane proceeded as expected, with loss of TMS to give homoallylic amines **7a**−**c**. Under these same conditions, vinyltrimethylsilane did not react.

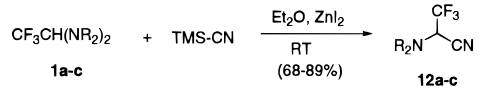


In a similar manner, and as reported earlier,[8] **1a** reacted with silyl enol ether **8** to form β-ketoamine **9**, which undergoes spontaneous elimination of dimethylamine to form α,β-unsaturated ketone **10**, and after 4 days of refluxing, alkene **11** was formed in its reaction with α-methylstyrene. Kubota reported a similar reaction of trifluoroacetaldyhyde hemiacetal with silyl enol ethers.[16]



Under these same conditions, neither styrene nor 1-octene underwent productive reaction.

Reactions with Trimethylsilyl Cyanide. Trifluoromethylated aminals **1a**−**c** reacted smoothly with TMS cyanide under room-temperature, anhydrous conditions with ZnI_2 in ether to give cyanoamines **12a**−**c**. Analogous cyanations using trifluoroacetaldehyde *O*,*O*-acetals,[16] *N*,*O*-acetals,[6c,d,f] and *O*,*S*-acetals[6a,b] had been reported earlier, generally under harsher conditions.



Conclusions

Lewis acid-catalyzed deamination of aminals **1a**−**c**, using ZnI_2 in ether, generates the respective 2,2,2-trifluoro-1,1-dialkylaminoethyl carbocations, **3**, which undergo synthetically useful electrophilic reactions with alkynes, electron-rich alkenes, and TMS cyanide to form trifluoromethyl alkynylamines, homoallylic amines, α,β-unsaturated ketones, and cyanoamines in fair to good yields. The results indicate that such aminals have considerable potential as reagents for incorporation of a CF_3 group into a variety of nucleophilic organic substrates.

Experimental Section

General Methods. Melting points and boiling points are uncorrected. NMR spectra were obtained in $CDCl_3$ using TMS as the internal standard for ^1H (300 MHz) and ^{13}C (75.43 MHz). ^{19}F NMR (282.4 MHz) spectra used $CFCl_3$ as internal standard. Diethyl ether and THF were distilled from sodium/benzophenone under nitrogen immediately prior to use. All reactions with air-sensitive compounds were carried out under a nitrogen atmosphere. Column chromatography was conducted using silica gel (230−400 mesh).

1-Phenyl-3-(dimethylamino)-4,4,4-trifluorobutyne (2a). Typical Procedure (A) for the Synthesis of Trifluoromethylated Propargylamines using CuI. A mixture of 1,1-bis(dimethylamino)-2,2,2-trifluoroethane (**1a**) (1.7 g, 10 mmol),[18]

(16) Kubota, T.; Iijima, M.; Tanaka, T. *Tetrahedron Lett.* **1992**, *33*, 1351.

(17) Klaver, W. J.; Moolenaar, M. J.; Hiemstra, H.; Speckamp, W. N. *Tetrahedron* **1988**, *44*, 3805 and references therein.

(18) Xu, Y.; Dolbier, W. R., Jr.; Rong, X. X. *J. Org. Chem.* **1997**, *62*, 1576.

Table 1. Reactions of Terminal Alkynes with 1,1-Bis(dialkylamino)trifluoroethane

aminal	alkyne	conditions (time)[a]	product	yield (%)
1a	phenyl	A (18 h)	**2a**	64
1a	phenyl	B (12 h)	**2a**	77
1a	1-hexyne	A (96 h)	**2b**	30
1a	1-hexyne	B (20 h)	**2b**	63
1	*p*-methylphenyl	A (36 h)	**2c**	55
1b	phenyl	A (72 h)	**2d**	54
1b	*p*-methylphenyl	B (31 h)	**2e**	65
1c	phenyl	A (4 days)	**2f**	50
1c	*p*-methylphenyl	B (48 h)	**2g**	56

[a] Conditions: (A) CuI, CH_3CN, reflux; (B) ZnI_2, THF, reflux.

phenylacetylene (1.02 g, 10 mmol), and CuI (1.9 g, 10 mmol) in anhydrous acetonitrile (20 mL) was refluxed with stirring for 18 h. After the mixture was cooled and filtered, the solvent was evaporated, and the residue was submitted to chromatography with hexanes−ether acetate (10:1) to give liquid product **2a** (1.3 g, 64%).

Procedure (B) for the Synthesis of Trifluoromethylated Propargylamines using ZnI_2. To a suspension of anhydrous zinc iodide (0.64 g, 2 mmol) in THF (10 mL) at room temperature were added 1,1-bis(dimethylamino)-2,2,2-trifluoroethane (**1a**)[18] (0.34 g, 2 mmol) and phenylacetylene (0.25 g, 2 mmol). The reaction mixture was refluxed with stirring overnight. ^{19}F NMR spectra showed that the starting material was gone after12 h of reflux. Water (10 mL) was added, and the mixture was extracted with ether. The combined extract was washed with brine and dried over $MgSO_4$. After evaporation of solvent, column chromatography of the residue with hexanes−ethyl acetate (10:1) gave product **2a** (0.35 g, 77%): bp 88−89 °C/3.5 mmHg; ^{1}H NMR δ 2.48 (s, 6H), 4.15 (q, J = 7.6 Hz, 1H), 7.32−7.38 (m, 3H), 7.48−7.54 (m, 2H); ^{19}F NMR δ −72.36 (d, J = 7.6 Hz, 3F); ^{13}C NMR δ 42.68, 60.36 (t, J = 32.2 Hz), 77.21, 88.82, 121.78, 123.85 (q, J = 282.5 Hz), 128.34, 128.91, 131.98; HRMS (CI) calcd for $C_{12}H_{13}NF_3$ (M + 1) 228.1000, found 228.1060. Anal. Calcd for $C_{12}H_{12}F_3N$: C, 63.44; H, 5.29; N, 6.17. Found: C, 63.05; H, 5.22; N, 6.32.

2-Dimethylamino-3,3,3-trifluorooctyne (2b). The reaction was complete after 20 h using procedure B (yield 63%): bp 120−122 °C/15 mmHg; ^{1}H NMR δ 0.93 (t, J = 7.0 Hz, 3H), 1.35−1.60 (m, 4H), 2.27 (td, J = 7.0, 2.0 Hz, 2H), 2.37 (s, 6H), 3.89 (qt, J = 7.6, 2.1 Hz, 1H); ^{19}F NMR δ −72.79 (d, J = 9.7 Hz, 3F); ^{13}C NMR δ 13.49, 18.23, 21.84, 30.58, 42.54, 59.83 (q, J = 31.2 Hz), 67.05, 89.68, 123.99 (q, J = 282.0 Hz); HRMS (CI) calcd for $C_{10}H_{16}F_3N$ (M^+ + 1) 207.1235, found 207.1250.

1-*p*-Methylphenyl-3-(dimethylamino)-4,4,4-trifluorobutyne (2c). The reaction was complete after 36 h using procedure A (yield 55%): bp 95−96 °C/3.5 mmHg; ^{1}H NMR δ 2.07 (s, 3H), 2.33 (s, 6H), 4.00 (q, J = 7.6 Hz, 1H), 6.89 (d, J = 7.9 Hz, 2H), 7.44 (d, J = 7.9 Hz, 2H); ^{19}F NMR δ −71.89 (d, J = 7.3 Hz, 3F); ^{13}C NMR δ 21.21, 42.54, 60.63 (q, J = 32.2 Hz), 77.31, 89.48, 119.29, 124.75 (q, J = 282.0 Hz), 129.36, 132.21, 139.16; HRMS (EI) calcd for $C_{13}H_{14}F_3N$ 241.1078, found 241.1056. Anal. Calcd for $C_{13}H_{14}F_3N$: C, 64.70; H, 5.81; N, 5.81. Found: C, 64.72; H, 5.82; N, 5.28.

1-Phenyl-3-piperidino-4,4,4-trifluorobutyne (2d). The reaction was complete after 72 h using procedure A (yield 54%): bp 135−137 °C/3.5 mmHg; ^{1}H NMR δ 1.38 (p, J = 5.6 Hz, 2H), 1.51−1.64 (m, 4H), 2.53−2.64 (m, 2H), 2.65−2.76 (m, 2H), 4.02 (q, J = 7.8 Hz, 1H), 7.21−7.31 (m, 3H), 7.38−7.46 (m, 2H); ^{19}F NMR δ −71.63 (d, J = 9.7 Hz); ^{13}C NMR δ 23.90, 26.11, 51.81, 60.97, (q, J = 32.1 Hz), 78.40, 88.25, 121.99, 124.02 (q, J = 282.9 Hz), 128.30, 128.77, 131.95; HRMS (EI) calcd for $C_{15}H_{16}F_3N$ 267.1235, found 267.1253.

1-*p*-Methylphenyl-3-piperidino-4,4,4-trifluorobutyne (2e). The reaction was complete after 31 h using procedure B (yield 65%): bp 120−122 °C/3.5 mmHg; ^{1}H NMR δ 1.44 (p, J = 5.6 Hz, 2H), 1.58−1.72 (m, 4H), 2.35 (s, 3H), 2.60−2.69 (m, 2H), 2.72−2.83 (m, 2H), 4.07 (q, J = 7.6 Hz, 1H), 7.13 (d, J = 7.9 Hz, 2H), 7.37 (d, J = 7.9 Hz, 2H); ^{19}F NMR δ −71.66 (d, J = 7.6 Hz, 3F); ^{13}C NMR δ 21.46, 23.91, 26.12, 51.78, 60.97 (q, J = 25.7 Hz), 77.64, 88.37, 118.90, 124.04 (q, J = 283.0 Hz), 129.04, 131.86, 138.97; HRMS (CI) calcd for $C_{16}H_{19}F_3N$ (M + 1) 282.1470, found 282.1469. Anal. Calcd for $C_{16}H_{18}F_3N$: C, 68.33; H, 6.41; N, 4.98. Found: C, 68.10; H, 6.62; N, 5.16.

1-Phenyl-3-morpholino-4,4,4-trifluorobutyne (2f). The reaction was complete after 48 h using procedure B (yield 56%): bp 135−137 °C/3.5 mmHg; ^{1}H NMR δ 2.60−2.72 (m, 2H), 2.72−2.82 (m, 2H), 3.69 (t, J = 4.4 Hz, 4H), 4.00 (q, J = 7.4 Hz, 1H), 7.23−7.32 (m, 3H), 7.38−7.46 (m, 2H); ^{19}F NMR δ −71.79 (d, J = 7.3 Hz, 3F); ^{13}C NMR δ 50.67, 60.52 (q, J = 32.1 Hz), 66.86, 77.24, 89.02, 121.56, 123.71 (q, J = 281.7 Hz), 128.34, 128.99, 131.95; HRMS (EI) calcd for $C_{14}H_{14}OF_3N$ 269.1027, found 269.1027.

1-Phenyl-2-trimethylsilyl-3-methylamino-4,4,4-trifluoro-1-butene (4). To a suspension of anhydrous zinc iodide (0.64 g, 2 mmol) in ether (10 mL) at room temperature were added 1,1-bis(dimethylamino)-2,2,2-trifluoroethane (0.34 g, 2 mmol) and propargytrimethylsilane (0.35 g, 2 mmol). The mixture was refluxed for 48 h, after which time the ^{19}F NMR spectrum showed that the starting material was gone. After the reaction mixture was cooled to room temperature, ether (20 mL) was added and the mixture filtered. The filtrate was washed with brine and dried with $MgSO_4$. After the solvent was removed, the residue was chromatographed. Elution with hexanes−ethyl acetate (10:1) gave product **4** (0.2 g, 35%): bp 75−77 °C/15 mmHg; ^{1}H NMR δ 0.015 (s, 9H), 2.53 (s, 3H), 3.82 (q, J = 7.3 Hz, 1H), 7.18−7.24 (m, 2H), 7.28−7.38 (m, 3H), 7.65 (m, 1H); ^{19}F NMR δ −72.94 (d, J = 7.3 Hz, 3F); ^{13}C NMR δ 0.33, 34.60, 64.20 (q, J = 27.5 Hz), 125.88 (q, J = 282.9 Hz), 127.52, 127.87, 128.37, 137.39, 139.30, 146.40; HRMS (CI) calcd for $C_{14}H_{21}F_3NSi$ (M^+ + 1) 288.1395, found 288.1395. Anal. Calcd for $C_{14}H_{20}F_3NSi$: C, 58.54; N, 4.88; H, 6.97. Found: C, 58.84; N, 5.03; H, 7.18.

1-Trimethylsilyl-3-(dimethylamino)-4,4,4-trifluorobutytyne (5). To a suspension of anhydrous zinc iodide (1.6 g, 5 mmol) in THF (10 mL) at room temperature were added 1,1-bis(dimethylamino)-2,2,2-trifluoroethane (0.85 g, 5 mmol) and (trimethylsilyl)acetylene (0.52 g, 5 mmol). The mixture was heated with stirring at 50 °C for 2 days. Then the reaction mixture was transferred at reduced pressure into a dry ice/acetone-cooled receiving flask (25 mL, round-bottom). After evaporation of solvent, the residue was distilled at reduced pressure to give a colorless liquid product **5** (0.59 g, 61%): bp 87−90 °C/110 mmHg; ^{1}H NMR δ 0.21 (s, 9H), 2.38 (s, 6H), 3.91 (q, J = 7.5 Hz, 1H); ^{19}F NMR δ −72.47 (d, J = 7.3 Hz, 3F); ^{13}C NMR δ − 0.23, 42.54, 60.38 (q, J = 31.7 Hz), 92.77, 94.56, 123.63 (q, J = 282.5 Hz); HRMS (CI) calcd for $C_9H_{17}F_3NSi$ (M^+ + 1) 224.1082, found 224.1014.

1-(Trimethylsilyl)-4-(dimethylamino)-5,5,5-trifluoro-2-pentyne (6). To a suspension of anhydrous zinc iodide (1.6 g, 5 mmol) in THF (10 mL) at room temperature were added 1,1-bis(dimethylamino)-2,2,2-trifluoroethane (0.85 g, 5 mmol) and propargytrimethylsilane (0.56 g, 5 mmol). The mixture was heated at 55 °C overnight, and the ^{19}F NMR spectrum showed that the reaction was finished. After the reaction mixture was cooled to room temperature, ether (20 mL) was added and the mixture filtered. The filtrate was washed with brine and dried with $MgSO_4$. After the solvent was removed, the residue was distilled at reduced pressure to give a colorless liquid product **6** (0.2 g, 52%): bp 75−77 °C/15 mmHg; ^{1}H NMR δ 0.12 (s, 9H), 1.55 (d, J = 2.44 Hz, 2H), 2.37 (s, 6H), 3.89 (qt, J = 7.3, 2.4 Hz, 1H); ^{19}F NMR δ −72.91 (d, J = 7.3 Hz, 3F); ^{13}C NMR δ −2.15, 6.99, 42.57, 60.00 (q, J = 31.7 Hz), 66.63, 87.66, 124.12 (q, J = 282.0 Hz); HRMS (EI) calcd for $C_{10}H_{18}F_3NSi$ 237.1161, found 237.1217. Anal. Calcd for $C_{10}H_{18}F_3NSi$: C, 50.63; H, 7.59; N, 5.91. Found: C, 50.55; H, 7.50; N, 5.93.

4-Dimethylamino-5,5,5-trifluoro-1-pentene (7a). The reaction procedure was the same as above (yield 50%): bp 100−102 °C; ^{1}H NMR δ 2.33−2.43 (m, 2H), 2.43 (q, J = 1.2 Hz, 6 H), 3.01−3.15 (m, 2H), 5.06−5.20 (m, 2H), 5.74−5.90 (m, 2H); ^{19}F NMR δ −69.46 (d, J = 7.3 Hz, 2F); ^{13}C NMR δ 30.28 (q, J = 2.0 Hz), 41.08, 64. 96 (q, J = 24.7 Hz), 116.99, 127.27 (q, J = 291.1 Hz), 134.50. (This compound could only be obtained in a relatively impure state.)

4-Piperidino-5,5,5-trifluoro-1-pentene (7b). To a suspension of anhydrous zinc iodide (3.2 g, 10 mmol) in ether (10 mL) at room temperature were added 1,1-bis(piperidino)-2,2,2-trifluoroethane (2.5 g, 10 mmol) and allyltrimethylsilane (1.14 g, 10 mmol). The mixture was stirred at reflux overnight. Ether (20 mL) was added and the mixture filtered. The filtrate was washed with brine and dried with $MgSO_4$. After the solvent was removed, the residue was distilled at reduced pressure to give a colorless liquid **7b** (1.2 g, 58%): bp 80−82 °C/6 mmHg; ^{1}H NMR δ 1.40−1.58 (m, 6H), 2.25−2.50 (m, 2H), 2.52−2.62 (m, 2H), 2.78−2.89 (m, 2H), 2.94−3.08 (m, 1H), 5.03−5.16 (m, 2H); 5.77−5.94 (m, 1H); ^{19}F NMR δ −69.36 (d, J = 7.3 Hz); ^{13}C NMR δ 24.72, 26.89, 30.38 (q, J = 1.5 Hz), 50.43, 65.97 (q, J = 24.7 Hz), 116.62, 127.24 (q, J = 292.1 Hz), 134.87; HRMS (EI) calcd for $C_{10}H_{16}F_3N$ 207.1235, found 207.1233.

4-Morpholino-5,5,5-trifluoro-1-pentene (7c). The reaction procedure was the same as above (yield 61%): bp 89−91 °C/6 mmHg; ^{1}H NMR δ 2.29−2.51 (m, 2H), 2.62−2.72 (m, 2H), 2.84−2.94 (m, 2H), 2.97−3.12 (m, 1H), 3.58−3.71 (m, 4H), 5.07−5.19 (m, 2H), 5.77−5.93 (m, 1H); ^{19}F NMR δ −69.71 (d, J = 7.3 Hz); ^{13}C NMR δ 29.93, 49.65, 65.42 (q, J = 25.2 Hz), 67.65, 117.23, 126.84 (q, J = 291.1 Hz), 134.17; HRMS (EI) calcd for $C_9H_{14}F_3NO$ 209.1027, found 209.1076.

1-Phenyl-4,4,4-trifluoro-2-buten-1-one (10). To a suspension of anhydrous zinc iodide (0.64 g, 2 mmol) in ether (20 mL) at room temperature was added 1,1-bis(dimethylamino)-2,2,2-trifluoroethane (0.34 g, 2 mmol). After the mixture was stirred for a few minutes, 1-phenyl-1-(trimethylsilyloxy)ethene (0.384 g, 2 mmol) was added. After the mixture was stirred at room temperature for 2 h, diethyl ether (20 mL) was added. The mixture was filtered and the filtrate washed with brine and dried with $MgSO_4$. After the solvent was evaporated, the residue was submitted to column chromatography with hexanes−ether acetate (10:1) to give product **10** (0.36 g, 90%): ^{1}H NMR δ 6.76−6.94 (m, 1H), 7.48−7.62 (m, 3H), 7.62−7.76 (1H), 7.94−8.06 (m, 2H); ^{19}F NMR δ −65.62 (d, J = 4.9 Hz, 3F); ^{13}C NMR δ 122.54 (q, J = 270.3 Hz), 128.78, 128.98, 129.99, 130.45, 130.03 (q, J = 4.6 Hz), 134.11, 136.14, 187.97; HRMS (EI) calcd for $C_{10}H_7F_3O$ 200.0449, found 200.0446.

2-Phenyl-4-(dimethylamino)-5,5,5-trifluoropentene (11). To a suspension of anhydrous zinc iodide (0.64 g, 2 mmol) in a solution of α-methylstyrene (0.24 g, 2 mmol) in ether (10 mL) at room temperature was added 1,1-bis(dimethylamino)-2,2,2-trifluoroethane (0.34 g, 2 mmol). After a few minutes of stirring at room temperature, the mixture was refluxed for 3 days. ^{19}F NMR spectra showed that the starting material was consumed. After cooling, the mixture was filtered, and the solvent was evaporated to give white residue, which was chromatographed. Elution with chloroform−hexane (1:10) gave product **11** (0.2 g, 41%): ^{1}H NMR δ 2.29 (s, 6H), 2.66−2.82 (m, 2H), 2.92−3.08 (m, 1H), 5.08 (s, 1H), 5.23 (s, 1H), 7.16−7.32 (m, 5H); ^{19}F NMR δ −69.34 (d, J = 7.3 Hz, 3F); ^{13}C NMR δ 32.21, 40.99, 62.95 (q, J = 26.7 Hz), 115.48, 127.43 (q, J = 291.6 Hz), 126.35, 127.61, 128.43, 140.15, 144.81; HRMS (EI) calcd for $C_{13}H_{16}F_3N$ 243.1235, found 243.1238.

2-Dimethylamino-3,3,3-trifluoropropanenitrile (12a). To a suspension of anhydrous zinc iodide (3.2 g, 10 mmol) in ether (10 mL) at room temperature were added 1,1-bis-(dimethylamino)-3,3,3-trifluoroethane (1.7 g, 10 mmol) and cyanotrimethylsilane (1.14 g, 10 mmol). The mixture was stirred at room temperature for 2 h. Ether (20 mL) was added and the mixture filtered. The filtrate was washed with brine and dried with $MgSO_4$. After the solvent was removed, the residue was distilled at reduced pressure to give a colorless liquid product **12a** (1.35 g, 89%): bp 70−72 °C/80 mmHg; ^{1}H NMR δ 2.47 (s, 6H), 4.12 (q, J = 7.3 Hz, 1H); ^{19}F NMR δ −71.09 (d, J = 7.3 Hz, 3F); ^{13}C NMR δ 42.98, 60.63 (q, J = 7.1 Hz), 109.90, 121.69 (q, J = 280.1 Hz); HRMS (EI) calcd for $C_5H_7F_3N_2$ 152.0561, found 152.0597.

2-Piperidino-3,3,3-trifluoropropanenitrile (12b). The reaction procedure was the same as above (yield: 70%): bp 82−84 °C/12 mmHg; ^{19}F NMR δ −70.44 (d, J = 7.3 Hz, 3F); ^{1}H NMR δ 1.49 (p, J = 5.7 Hz, 2H), 1.60−1.70 (m, 4H), 2.55−2.65 (m, 2H), 2.71−2.82 (m, 2H), 4.05 (q, J = 7.3 Hz, 1H); ^{13}C NMR δ 23.25, 25.62, 52.21, 60.99 (q, J = 33.2 Hz), 110.39, 121.84 (q, J = 283.1 Hz); HRMS (EI) calcd for $C_8H_{11}F_3N_2$ 192.0874, found 192.0873.

2-Morpholino-3,3,3-trifluoropropanenitrile (12c). The reaction procedure was the same as above (yield: 68%): bp 100−102 °C/12 mmHg; ^{19}F NMR δ −70.42 (d, J = 7.3 Hz); ^{1}H NMR δ 2.65−2.73 (m, 2H), 2.78−2.88 (m, 2H), 3.77 (m, 4H), 4.11 (q, J = 7.3 Hz, 1H); ^{13}C NMR δ 50.87, 60.24 (q, J = 33.7 Hz), 66.24, 109.87, 121.61 (q, J = 283.0 Hz); HRMS calcd for $C_7H_9OF_3N_2$ 194.0677, found 194.0665.

Acknowledgment. Support of this research in part by the National Science Foundation is gratefully acknowledged.

Supporting Information Available: ^{1}H, ^{13}C, and ^{19}F NMR spectra of compounds **2b**,**d**,**f**, **5**, **7a**−**c**, **10**, **11**, **12a**−**c**. This material is available free of charge via the Internet at http://pubs.acs.org.

JO991750Y