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Aza Diels—Alder reactions of methyl trifluoropyruvate sulfonyl- and phosphorylimines with 1,3-dienes

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2-Trifluoromethyl-substituted 1,2,3,6-tetrahydro-2-pyridyl carboxylates were synthesized in one step by the aza Diels—Alder reactions of methyl trifluoropyruvate sulfonyl- and phosphorylimines with 1,3-dienes.

Key words: aza Diels—Alder reaction, 1,2,3,6-tetrahydro-2-pyridyl carboxylates, methyl trifluoropyruvate imines, 1,3-dienes.

Cyclic α-amino acids play an important role in the design of efficient medicines.[1] The introduction of the fluorine atoms or fluoroalkyl groups into the molecules of these compounds opens up new possibilities because these substituents generally lead to a substantial improvement in the physicochemical and biological properties both of amino acids and their derived peptides.[2]

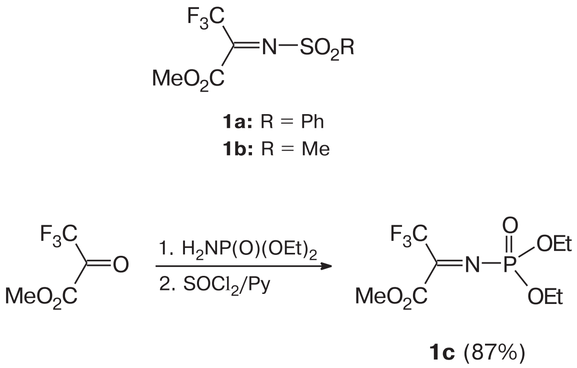
As part of our continuing investigations on the synthesis of fluorine-containing cyclic α-amino acids,[3] we developed a simple procedure for the preparation of 2-CF_3-substituted 1,2,3,6-tetrahydro-2-pyridyl carboxylates (structural analogs of natural *L*-4,5-dehydropipecolic acid[4]) based on the aza Diels—Alder reaction[5] of highly electrophilic methyl trifluoropyruvate imines[6] with 1,3-dienes.

In our previous studies, we have demonstrated[7] that methyl trifluoropyruvate acylimines possessing the conjugated C=N—C=O system behave as 1,3-oxaza-1,3-dienes in reactions with various alkenes, including active ene components and even 1,3-dienes, to give the corresponding oxadiazines as [2+4] cycloaddition products. However, after the replacement of the acyl group at the nitrogen atom by the sulfonyl group, methyl trifluoropyruvate imines proved to be active enophiles with respect to ene components (2-methylpropene, methylenecycloalkanes, *etc.*) and selectively formed linear products of the imino ene reaction.[8] Hence, there were grounds to expect that sulfonyl- and phosphorylimines would exhibit exclusively the properties of dienophiles in the reactions with 1,3-dienes.

Results and Discussion

To study the characteristic features of the behavior of methyl trifluoropyruvate imines in the aza Diels—Alder reaction, we used sulfonylimines **1a,b** [6] and phosphorylimine **1c** as dienophiles. Compound **1c** was prepared from diethyl phosphoramidate and methyl trifluoropyruvate in 87% yield (Scheme 1).

Scheme 1



Cyclopentadiene, 2,3-dimethyl-1,3-butadiene, isoprene, 2-trimethylsilyloxy-1,3-butadiene, and piperylene (containing 75% of the *trans* isomer) were examined as 1,3-dienes in the reactions of imines **1**. The reactions were carried out in anhydrous CH_2Cl_2 in the presence of a twofold excess of 1,3-diene. The course of the reactions was monitored by TLC and ^{19}F NMR spectroscopy.

We found that imines **1a—c** vigorously reacted with active 1,3-dienes resulting in polymerization and numerous transformations of the latter even at −20 °C. The aza Diels—Alder reaction products were obtained in high yields only when the reagents were mixed and the reactions were conducted under milder conditions. The experimentally determined conditions under which the re-

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† Deceased.

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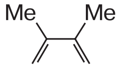
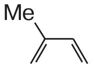
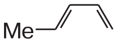
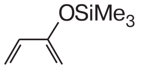
Table 1. Conditions of the selective reactions of imines **1** with 1,3-dienes

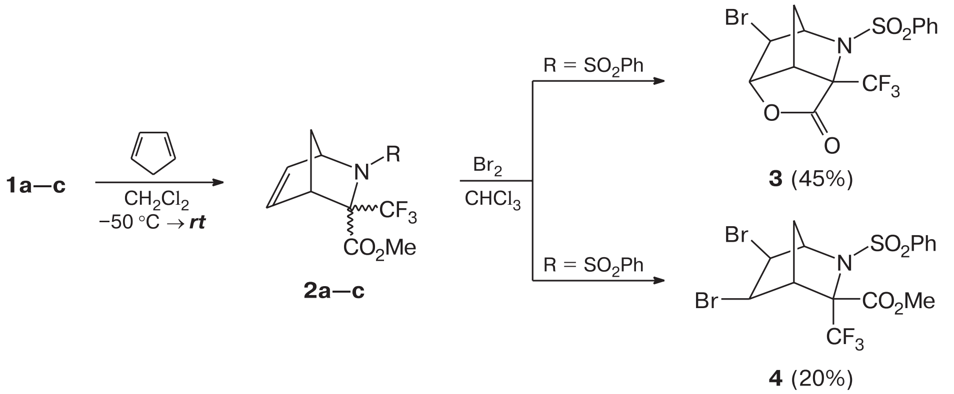
1,3-Diene	Temperature of mixing/°C			Reaction temperature/°C (reaction time/h)		
	1a	**1b**	**1c**	**1a**	**1b**	**1c**
	–75	–75	–50	–75 (5)—–50 (5)	–75 (6)—–50 (6)	–50 (24)
	–50	–50	–50	–30(5) → 20(8)	–30(6) → 20(8)	20 (120)
	–50	–50	–50	–30(5) → 20(8)	–30(5) → 20(8)	20 (150)
	–20	–20	–20	4 (120)	—	20 (720)
	–50	–50	–50	–50(6) → 20(8)	—	20 (48)

actions of imines **1a—c** with 1,3-dienes proceeded selectively are given in Table 1.

Cyclopentadiene proved to be a particularly active diene in the reactions with imines **1**. Its reactions with imines started even at –75 °C (see Table 1) and were completed at –50 °C to give products **2a,b** in *ca.* 100% yields. Phosphorylimine **1c** was also almost completely transformed into [4+2] cycloadduct **2c**. However, the latter reaction required more prolonged stirring at –50 °C. According to the ^{1}H and ^{19}F NMR spectroscopic data, azanorbornenes **2** were formed as mixtures of the *endo* and *exo* isomers in a ratio of 3 : 1 (**2a,b**) or 4 : 1 (**2c**). The configurations of isomers **2a** were proved by bromination giving rise to lactone **3** and dibromide **4** as the major and minor products, respectively (Scheme 2).

2,3-Dimethyl-1,3-butadiene and isoprene reacted with sulfonylimines **1a,b** also under mild conditions to give the corresponding cycloadducts **5** (Scheme 3, Table 2). Phosphorylimine **1c** is less reactive with respect to these 1,3-dienes. Thus, [4+2] cycloaddition of **1c** proceeded with a noticeable rate only at room temperature and was completed in several days (see Table 1). The reactions of imines **1** with isoprene proceeded regiospecifically to form, like most of the reactions described in the literature,[9] 4-methyl-substituted tetrahydropyridines **5d—f**. The second possible regioisomer is not formed as evidenced by the presence of only one set of signals in the ^{1}H NMR spectra and the only signal of the CF$_3$ group in the ^{19}F NMR spectra. The position of the methyl group in the ring was established based on the fact that the signals of the CH$_2$ groups adjacent to the asymmetric center are observed as a characteristic AB system consisting of well-resolved narrow signals. At the same time, the signals of the AB system of the protons of the NCH$_2$ group are broadened, like the signals of the

Scheme 2



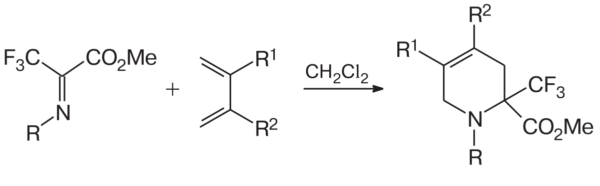
2a: R = SO$_2$Ph (98%); **2b:** R = SO$_2$Me (88%); **2c:** R = P(O)(OEt)$_2$ (98%)

Table 2. Pyridyl carboxylates **5a—f**

Compound	R^1	R^2	R	Yield (%)
5a	Me	Me	SO_2Ph	71
5b	Me	Me	SO_2Me	91
5c	Me	Me	$P(O)(OEt)_2$	95
5d	H	Me	SO_2Ph	81
5e	H	Me	SO_2Me	97
5f	H	Me	$P(O)(OEt)_2$	68

vinyl atom of the H-ring, which indicates that they are bound to the adjacent carbon atoms.

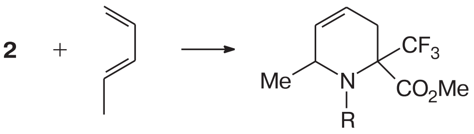
Scheme 3



1 **5**

As expected, the reactions of piperylene with imines **1a,c** proceeded less vigorously. To prevent side transformations, the reagents were mixed at –20 °C and the reaction mixture was kept in a refrigerator (4 °C) for several days or at room temperature until the reactions was completed (see Table 1). In both cases, products **6a,b** (according to the ^{19}F NMR spectroscopic data) were formed as mixtures of diastereomers in a ratio of 1 : 10 (**6a**) or 1 : 1.5 (**6b**) (Scheme 4). The regioselectivity of the reaction was judged from the absence of the AB system of the methylene protons in the characteristic region of the ^{1}H NMR spectra (δ_{AB} *ca.* 4) corresponding to the NCH_2 group of the alternative structure.

Scheme 4

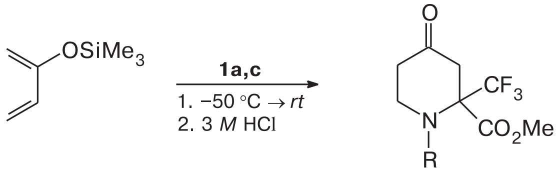


6a,b

6a: R = SO_2Ph (75%);
6b: R = $P(O)(OEt)_2$ (89%).

2-Trimethylsiloxy-1,3-butadiene also selectively reacted with imines **1a,c** (see Table 1). The reactions afforded the expected analogs of natural 4-oxopipecolic acid**[10]** **7a,b** in preparative yields (Scheme 5). In the ^{1}H NMR spectra of compounds **7**, the signals for the protons of the methylene group adjacent to the asymmetric center, like those in the spectra of isoprene and piperylene, are observed as an uncomplicated AB system, whereas the signals for each of the methylene protons in the AB systems for the NCH_2 and $NCH_2C\underline{H}_2$ groups are more complicated, which indicates that they are located in the adjacent positions.

Scheme 5



7a,b

7a: R = SO_2Ph (73%);
7b: R = $P(O)(OEt)_2$ (61%).

In conclusion, it should be mentioned that we found the optimum conditions under which the aza Diels—Alder reactions of 1,3-dienes with highly electrophilic imines **1a—c** bearing three electron-withdrawing substituents at the C=N bond proceeded selectively. Since all compounds thus obtained are analogs of natural 4,5-dehydro- and 4-oxopipecolic acids, they are of interest as potential low-molecular-weight biological regulators and can be used for modifications of biologically active peptides.

Experimental

All reactions were carried out with the use of the freshly distilled reagents and anhydrous solvents. The ^{1}H NMR spectra were recorded on a Bruker AMX-400 spectrometer (400 MHz). The ^{19}F and ^{31}P NMR spectra were measured on a Bruker WR-SY instrument (188 MHz and 81 MHz, respectively). The chemical shifts are given in the δ scale relative to hexamethyldisiloxane (HMDS) (internal standard) and with respect to trifluoroacetic and phosphoric acids (external standard), respectively. The R_f values were determined on TLC plates (Merck, 60 F-254, 0.25 mm). The compounds were purified by column chromatography with silica gel (Kieselgel 60, 0.063—0.200 mm). Mixtures of ethyl acetate (EA) and light petroleum (LP) were used as the eluents.

Methyl 2-(diethoxyphosphorylimino)-3,3,3-trifluoropropionate (1c). Methyl trifluoropyruvate (7.80 g, 0.05 mol) was added with stirring to a solution of diethyl phosphoramidate (7.65 g, 0.05 mol) in dry benzene (50 mL). The reaction mixture was cooled to 10 °C and a solution of pyridine (7.9 g, 0.1 mol) in benzene (10 mL) was added dropwise. The reaction mixture was stirred at ~20 °C for 0.5 h and cooled to 5 °C. Then a solution of thionyl chloride (5.95 g, 0.05 mol) in the same solvent (10 mL) was added dropwise. The reaction mixture was refluxed for 2 h and then kept for 12 h. The solution of the product was decanted from the precipitate, the benzene was removed *in vacuo*, and the residue was dissolved in Freon-113

($CFCl_2$—CF_2Cl, 40 mL). After separation of insoluble impurities by fractionation, pure product **1c** was obtained in a yield of 12.6 g (87%), b.p. 80—82 °C (1 Torr). Found (%): C, 33.04; H, 4.50; N, 5.05. $C_8H_{13}F_3NO_5P$. Calculated (%): C, 32.99; H, 4.47; N, 4.81. ^1H NMR ($CDCl_3$), δ: 4.01 (m, 4 H, 2 OCH_2); 3.71 (s, 3 H, OMe); 1.11 (t, 6 H, 2 Me, $^3J_{H,H}$ = 14.1 Hz). ^{19}F NMR, ($CDCl_3$), δ: 5.4 (s, 3 F, CF_3). ^{31}P NMR ($CDCl_3$), δ: –1.5 (P=O).

3-Methoxycarbonyl-2-phenylsulfonyl-3-trifluoromethyl-2-azabicyclo[2.2.1]hept-5-ene (2a). Cyclopentadiene (6.8 mmol) was added to a solution of imine **1a** (3.4 mmol) in dichloromethane (5 mL) at –78 °C (see Table 1). The reaction mixture was kept at from –75 to –50 °C for 5 h and then warmed to ~20 °C. The solvent was removed *in vacuo* and the product was purified by column chromatography. The yield was 98% (mixture of *endo/exo* isomers, 3 : 1), m.p. 98—99 °C, R_f 0.47 (EA : LP = 1 : 2). Found (%): C, 49.68; H, 3.63; N, 3.88. $C_{15}H_{14}F_3NO_4S$. Calculated (%): C, 49.86; H, 3.91; N, 3.88. ^1H NMR ($CDCl_3$), δ, *endo*-**2a**: 7.95 (m, 2 H, Ph); 7.52 (m, 3 H, Ph); 6.52 (m, 1 H, =CH); 6.31 (s, 1 H, =CH); 4.59 (s, 1 H, NCH); 3.89 (s, 3 H, OMe); 3.76 (s, 1 H, CH); 1.89 and 1.51 (both d, 1 H each, CH_2, $^2J_{H,H}$ = 9.2 Hz). ^{19}F NMR ($CDCl_3$), δ, *endo*-**2a**: 3.89 (s, CF_3). ^1H NMR ($CDCl_3$), δ, *exo*-**2a**: 7.95 (m, 2 H, Ph); 7.52 (m, 3 H, Ph); 6.54 (m, 1 H, =CH); 6.14 (m, 1 H, =CH); 4.55 (s, 1 H, NCH); 3.85 (s, 1 H, CH); 3.77 (s, 3 H, OMe); 2.00 and 1.49 (both d, 1 H each, CH_2, $^2J_{H,H}$ = 9.2 Hz). ^{19}F NMR ($CDCl_3$), δ, *exo*-**2a**: 3.77 (s, CF_3).

Compounds **2b,s**, **5**, and **6** were prepared analogously to compound **2a** (see Table 1).

3-Methoxycarbonyl-2-methylsulfonyl-3-trifluoromethyl-2-azabicyclo[2.2.1]hept-5-ene (2b) (mixture of *endo/exo* isomers, 3 : 1). The yield was 88%, m.p. 79—81 °C, R_f 0.25 (EA : LP = 1 : 2). Found (%): C, 40.01; H, 3.80; N, 4.89. $C_{10}H_{12}F_3NO_4S$. Calculated (%): C, 40.13; H, 4.04; N, 4.68. ^1H NMR (acetone-d_6), δ, *endo*-**2b**: 6.79 (m, 1 H, =CH); 6.40 (m, 1 H, =CH); 4.79 (s, 1 H, NCH); 3.89 (s, 3 H, OMe); 3.84 (s, 1 H, CH); 3.19 (s, 3 H, SMe); 1.95 and 1.62 (both d, 1 H each, CH_2, $^2J_{H,H}$ = 8.8 Hz). ^{19}F NMR (acetone-d_6), δ, *endo*-**2b**: 16.46 (s, CF_3). ^1H NMR (acetone-d_6), δ, *exo*-**2b**: 6.93 (m, 1 H, =CH); 6.38 (m, 1 H, =CH); 4.82 (s, 1 H, NCH); 3.92 (s, 1 H, CH); 3.79 (s, 3 H, OMe); 3.14 (s, 3 H, SMe); 2.00 and 1.59 (both d, 1 H each, CH_2, $^2J_{H,H}$ = 8.8 Hz). ^{19}F NMR (acetone-d_6), δ, *exo*-**2b**: 14.00 (s, CF_3).

2-Diethoxyphosphoryl-3-methoxycarbonyl-3-trifluoromethyl-2-azabicyclo[2.2.1]hept-5-ene (2c) (mixture *endo/exo* isomers, 4 : 1). The yield was 98%, colorless oil, R_f 0.33 (EA : LP = 2 : 1). Found (%): C, 43.49; H, 5.30; N, 4.09. $C_{13}H_{19}F_3NO_5P$. Calculated (%): C, 43.69; H, 5.32; N, 3.92. ^1H NMR ($CDCl_3$), δ, *endo*-**2c**: 6.61 (m, 1 H, =CH); 6.29 (m, 1 H, =CH); 4.41 (s, 1 H, NCH); 4.21 (m, 4 H, 2 OCH_2); 3.87 (s, 3 H, OMe); 3.72 (s, 1 H, CH); 1.77 and 1.51 (both d, 1 H each, CH_2, $^2J_{H,H}$ = 8.8 Hz); 1.32 (m, 6 H, 2 Me). ^{19}F NMR ($CDCl_3$), δ, *endo*-**2c**: 15.6 (s, CF_3). ^1H NMR ($CDCl_3$), δ, *exo*-**2c**: 6.60 (m, 1 H, =CH); 6.11 (m, 1 H, =CH); 4.42 (s, 1 H, NCH); 4.01 (m, 4 H, 2 OCH_2); 3.77 (s, 1 H, CH); 3.75 (s, 3 H, OMe); 1.97 and 1.48 (both d, 1 H each, CH_2, $^2J_{H,H}$ = 8.8 Hz); 1.29 (m, 6 H, 2 Me). ^{19}F NMR ($CDCl_3$), δ, *exo*-**2c**: 13.15 (s, CF_3).

Bromination of compound 2a. A mixture of compound **2a** (2.5 g, 6.9 mmol) and Br_2 (1.2 g, 7.5 mmol) in $CHCl_3$ (20 mL) was kept in a sealed tube at ~20 °C for one week. The solvent was removed *in vacuo* and the residue was chromatographed on a column (EA : LP = 1 : 5).

4-Bromo-2-phenylsulfonyl-1-trifluoromethyl-2-aza-6-oxatricyclo[3.2.1.1^{3,8}]nonan-7-one (3a). The yield was 45%, m.p. 175—176 °C, R_f 0.42 (EA : LP = 1 : 5). Found (%): C, 39.17; H, 2.59; N, 3.16. $C_{14}H_{11}BrF_3NO_4S$. Calculated (%): C, 39.46; H, 2.58; N, 3.28. ^1H NMR (acetone-d_6), δ: 7.95 (m, 2 H, Ph); 7.62 (m, 3 H, Ph); 5.25 (m, 1 H, CHBr); 4.75 (m, 2 H, OCH); 4.45 (m, 1 H, NCH); 4.09 (m, 1 H, CH); 2.49 and 2.18 (both m, 1 H each, CH_2). ^{19}F NMR (acetone-d_6), δ: 10.8 (s, CF_3).

5,6-Dibromo-3-methoxycarbonyl-2-phenylsulfonyl-3-trifluoromethyl-2-azabicyclo[2.2.1]heptane (4). The yield was 20%, m.p. 158—159 °C, R_f 0.62 (EA : LP = 1 : 5). Found (%): C, 35.62; H, 2.44; N, 2.47. $C_{15}H_{14}Br_2F_3NO_4S$. Calculated (%): C, 35.50; H, 2.40; N, 2.70. ^1H NMR, (acetone-d_6), δ: 7.97 (m, 2 H, Ph); 7.65 (m, 3 H, Ph); 4.45 (m, 2 H, CHBr—CHBr); 4.01 (m, 1 H, NCH); 3.82 (s, 3 H, OMe); 3.31 (m, 1 H, CH); 2.63 and 2.31 (both m, 1 H each, CH_2). ^{19}F NMR (acetone-d_6), δ: 9.5 (s, CF_3).

Methyl 4,5-dimethyl-1-phenylsulfonyl-2-trifluoromethyl-1,2,3,6-tetrahydropyridine-2-carboxylate (5a). The yield was 71%, m.p. 69—71 °C, R_f 0.6 (EA : LP = 1 : 3). Found (%): C, 50.69; H, 4.62; N, 3.73. $C_{16}H_{18}F_3NO_4S$. Calculated (%): C, 50.93; H, 4.77; N, 3.71. ^1H NMR ($CDCl_3$), δ: 7.95 (m, 2 H, Ph); 7.55 (m, 3 H, Ph); 3.88 (s, 3 H, OMe); 3.64 and 3.45 (both d, AB system, 1 H each, NCH_2, $^2J_{H,H}$ = 15.0 Hz); 2.82 and 2.66 (both d, AB system, 1 H each, CH_2, $^2J_{H,H}$ = 15.9 Hz); 1.65 (s, 3 H, Me); 1.55 (s, 3 H, Me). ^{19}F NMR ($CDCl_3$), δ: 6.6 (s, CF_3).

Methyl 4,5-dimethyl-1-methylsulfonyl-2-trifluoromethyl-1,2,3,6-tetrahydropyridine-2-carboxylate (5b). The yield was 91%, m.p. 128—130 °C, R_f 0.27 (EA : LP = 1 : 4). Found (%): C, 42.00; H, 5.21; N, 4.46. $C_{11}H_{16}F_3NO_4S$. Calculated (%): C, 41.90; H, 5.08; N, 4.44. ^1H NMR ($CDCl_3$), δ: 3.78 (s, 3 H, OMe); 3.89 and 3.72 (both d, AB system, 1 H each, NCH_2, $^2J_{H,H}$ = 16.2 Hz); 3.07 (s, 3 H, SMe); 2.78 and 2.56 (both d, AB system, 1 H each, CH_2, $^2J_{H,H}$ = 16.9 Hz); 1.72 (m, 6 H, 2 Me). ^{19}F NMR ($CDCl_3$), δ: 6.6 (s, CF_3).

Methyl 1-diethoxyphosphoryl-4,5-dimethyl-2-trifluoromethyl-1,2,3,6-tetrahydropyridine-2-carboxylate (5c). The yield was 95%, pale-yellow oil, R_f 0.47 (EA : LP = 1 : 2). Found (%): C, 45.04; H, 6.17; N, 3.75. $C_{14}H_{23}F_3NO_5P$. Calculated (%): C, 45.23; H, 6.31; N, 3.61. ^1H NMR ($CDCl_3$), δ: 4.05 (m, 4 H, 2 OCH_2); 3.78 (s, 3 H, OMe); 3.47 and 3.40 (both d, AB system, 1 H each, NCH_2, $^2J_{H,H}$ = 15.4 Hz); 2.63 and 2.42 (both d, AB system, 1 H each, CH_2, $^2J_{H,H}$ = 16.2 Hz); 1.66 (m, 6 H, 2 Me); 1.29 (t, 6 H, 2 Me, $^3J_{H,H}$ = 7.1 Hz). ^{19}F NMR ($CDCl_3$), δ: 4.6 (s, CF_3).

Methyl 4-methyl-1-phenylsulfonyl-2-trifluoromethyl-1,2,3,6-tetrahydropyridine-2-carboxylate (5d). The yield was 81%, m.p. 94—96 °C, R_f 0.39 (EA : LP = 1 : 3). Found (%): C, 49.87; H, 4.42; N, 3.88. $C_{15}H_{16}F_3NO_4S$. Calculated (%): C, 49.59; H, 4.41; N, 3.86. ^1H NMR (DMSO-d_6), δ: 7.91 (m, 2 H, Ph); 7.62 (m, 3 H, Ph); 5.48 (br.s, 1 H, =CH); 3.84 (s, 3 H, OMe); 3.74 and 3.59 (both br.d, AB system, 1 H each, NCH_2, $^2J_{H,H}$ = 14.5 Hz); 2.81 and 2.58 (both d, AB system, 1 H each, CH_2, $^2J_{H,H}$ = 15.2 Hz); 1.72 (s, 3 H, Me). ^{19}F NMR ($CDCl_3$), δ: 9.6 (s, CF_3).

Methyl 4-methyl-1-methylsulfonyl-2-trifluoromethyl-1,2,3,6-tetrahydropyridine-2-carboxylate (5e). The yield was 97%, m.p. 65—67 °C, R_f 0.57 (EA : LP = 1 : 3). Found (%):

C, 39.82; H, 4.60; N, 4.69. $C_{10}H_{14}F_3NO_4S$. Calculated (%): C, 39.87; H, 4.65; N, 4.65. ^{1}H NMR (acetone-d_6), δ: 5.68 (br.s, 1 H, =CH); 3.79 (s, 3 H, OMe); 4.04 and 3.72 (both br.d, AB system, 1 H each, NCH_2, $^2J_{H,H}$ = 16.1 Hz); 3.07 (s, 3 H, SMe); 2.78 and 2.56 (both d, AB system, 1 H each, CH_2, $^2J_{H,H}$ = 16.0 Hz); 1.76 (s, 3 H, Me). ^{19}F NMR (acetone-d_6), δ: 6.1 (s, CF_3).

Methyl 1-diethoxyphosphoryl-4-methyl-2-trifluoromethyl-1,2,3,6-tetrahydropyridine-2-carboxylate (5f). The yield was 68%, m.p. 63—65 °C, R_f 0.64 (EA : LP = 1 : 1). Found (%): C, 43.60; H, 5.83; N, 3.96. $C_{13}H_{21}F_3NO_5P$. Calculated (%): C, 43.45; H, 5.85; N, 3.89. ^{1}H NMR ($CDCl_3$), δ: 5.52 (br.s, 1 H, =CH); 4.06 (m, 4 H, 2 OCH_2); 3.80 (s, 3 H, OMe); 3.65 and 3.52 (both br.d, AB system, 1 H each, NCH_2, $^2J_{H,H}$ = 17.1 Hz); 2.67 and 2.40 (both d, AB system, 1 H each, CH_2, $^2J_{H,H}$ = 17.2 Hz); 1.71 (s, 3 H, Me); 1.26 (t, 6 H, 2 Me, $^3J_{H,H}$ = 6.8 Hz). ^{19}F NMR ($CDCl_3$), δ: 4.9 (s, CF_3). ^{31}P NMR ($CDCl_3$), δ: 6.49 (P=O).

Methyl 6-methyl-1-phenylsulfonyl-2-trifluoromethyl-1,2,3,6-tetrahydropyridine-2-carboxylate (6a) (mixture of diastereomers, 10 : 1). The yield was 75%, m.p. 75—77 °C, R_f 0.46 (EA : LP = 1 : 3). Found (%): C, 49.87; H, 4.40; N, 3.91. $C_{15}H_{16}F_3NO_4S$. Calculated (%): C, 49.59; H, 4.41; N, 3.86. **Diastereomer A.** ^{1}H NMR (acetone-d_6), δ: 7.91 (m, 2 H, Ph); 7.51 (m, 3 H, Ph); 6.12 and 5.84 (both m, 1 H each, CH=CH); 4.32 (m, 1 H, NCH); 3.79 (s, 3 H, OMe); 2.68 (m, 2 H, CH_2); 0.96 (d, 3 H, Me, $^3J_{H,H}$ = 6.8 Hz). ^{19}F NMR (acetone-d_6), δ: 5.4 (s, CF_3). **Diastereomer B.** ^{1}H NMR (acetone-d_6), δ: 7.91 (m, 2 H, Ph); 7.51 (m, 3 H, Ph); 5.94 and 5.76 (both m, 1 H each, CH=CH); 4.24 (m, 1 H, NCH); 3.87 (s, 3 H, OMe); 2.68 (m, 2 H, CH_2); 1.31 (m, 3 H, Me). ^{19}F NMR (acetone-d_6), δ: 11.9 (s, CF_3).

Methyl 1-diethoxyphosphoryl-6-methyl-2-trifluoromethyl-1,2,3,6-tetrahydropyridine-2-carboxylate (6b) (mixture of diastereomers, 1.5 : 1). The yield was 89%, colorless oil, R_f 0.33 (EA : LP = 1 : 1). Found (%): C, 43.58; H, 5.89; N, 3.90. $C_{13}H_{21}F_3NO_5P$. Calculated (%): C, 43.69; H, 5.85; N, 3.89. **Diastereomer A.** ^{1}H NMR ($CDCl_3$), δ: 6.15 and 5.21 (both m, 1 H each, CH=CH); 4.15 (m, 1 H, NCH); 4.09 (m, 4 H, 2 OCH_2); 3.74 (s, 3 H, OMe); 2.64 (m, 2 H, CH_2); 1.29 (m, 6 H, 2 Me); 1.20 (m, 3 H, Me). ^{19}F NMR ($CDCl_3$), δ: 4.8 (s, CF_3). **Diastereomer B.** ^{1}H NMR ($CDCl_3$), δ: 5.84 (m, 2 H, CH=CH); 4.13 (m, 1 H, NCH); 4.07 (m, 4 H, 2 OCH_2); 3.79 (s, 3 H, OMe); 2.55 (m, 2 H, CH_2); 1.37 (d, 3 H, Me, $^3J_{H,H}$ = 6.8 Hz); 1.28 (m, 6 H, 2 Me). ^{19}F NMR ($CDCl_3$), δ: 10.5 (s, CF_3).

Synthesis of compounds 7 (general procedure). A solution of 2-trimethylsilyloxy-1,3-butadiene (3.0 mmol) in dichloromethane (3 mL) was added to a solution of imine **1** (2.0 mmol) in the same solvent (5 mL) at −50 °C. The reaction mixture was kept under the conditions given in Table 1, diluted with ether (50 mL), and then extensively shaken with 3 *M* HCl (50 mL) in a separating funnel. The organic layer was separated, dried with $MgSO_4$, and concentrated on a rotary evaporator. The product was purified by column chromatography (EA : LP = 1 : 1).

Methyl 4-oxo-1-phenylsulfonyl-2-trifluoromethyl-1,2,3,6-tetrahydropyridine-2-carboxylate (7a). The yield was 73%, m.p. 134—136 °C, R_f 0.30 (EA : LP = 1 : 2). Found (%): C, 46.17; H, 4.01; N, 3.89. $C_{14}H_{14}F_3NO_5S$. Calculated (%): C, 46.03; H, 3.84; N, 3.84. ^{1}H NMR ($CDCl_3$), δ: 7.91 (m, 2 H, Ph); 7.63 (m, 3 H, Ph); 3.89 (s, 3 H, OMe); 3.84 and 3.58 (both m, 1 H each, NCH_2); 3.00 and 2.85 (both d, AB system, 1 H each, CH_2, $^2J_{H,H}$ = 16.0 Hz); 2.79 and 2.45 (both m, 1 H each, CH_2). ^{19}F NMR ($CDCl_3$), δ: 3.5 (s, CF_3).

Methyl 1-diethoxyphosphoryl-4-oxo-2-trifluoromethyl-1,2,3,6-tetrahydropyridine-2-carboxylate (7b). The yield was 61%, m.p. 67—69 °C, R_f 0.29 (EA : LP = 1 : 1). Found (%): C, 39.98; H, 5.26; N, 3.84. $C_{12}H_{19}F_3NO_6P$. Calculated (%): C, 39.89; H, 5.26; N, 3.88. ^{1}H NMR ($CDCl_3$), δ: 4.08 (m, 4 H, 2 OCH_2); 3.73 (s, 3 H, OMe); 3.62 (m, 2 H, NCH_2); 3.26 and 2.63 (both d, AB system, 1 H each, CH_2, $^2J_{H,H}$ = 16.0 Hz); 2.60 and 2.49 (both m, 1 H each, CH_2); 1.29 (m, 6 H, 2 Me). ^{19}F NMR ($CDCl_3$), δ: 2.4 (s, CF_3).

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