2.83 mmol). The solution was stirred for 40 min, and the resulting white solids were removed by filtration. The filtrate was concentrated in vacuo, and the residue was dissolved in water (70 mL). This aqueous solution was extracted with CH_2Cl_2 (100 mL × 3). The extracts were dried over Na_2SO_4 and concentrated in vacuo to give (2*S*,3*R*,4*R*,5*R*)-3-ethyl-4,5-(isopropylidenedioxy)-3-methyltetrahydrofuran-2-carboxaldehyde (**6**) as a colorless syrup, which was subjected to the next step directly. **6**: TLC R_f 0.85 (AcOEt/hexane (1:1)); ^{1}H NMR (90 MHz) δ 0.95 (s, 3 H, CH_3-3), 0.97 (t, 3 H, *J* = 8 Hz, CH_3CH_2-3), 1.33, 1.52 (each s, each 3 H, $C(CH_3)_2$), 1.52–1.97 (m, 2 H, CH_3CH_2-3), 4.02 (d, 1 H, *J* = 2 Hz, H-2), 4.13 (d, 1 H, *J* = 4 Hz, H-4), 5.90 (d, 1 H, *J* = 4 Hz, H-5), 9.70 (d, 1 H, *J* = 2 Hz, CHO).

To a mixture of potassium permanganate (746 mg, 4.72 mmol) and benzyltriethylammonium chloride (55 mg) in water (5 mL) was added a solution of **6** in methanol (2 mL). The mixture was stirred for 2.5 h and methanol (2 mL) was added. The insoluble solids were removed by filtration, and the filtrate was diluted with water (50 mL). This aqueous solution was extracted with AcOEt (100 mL × 5). The combined extracts were dried over Na_2SO_4 and concentrated in vacuo to give crude carboxylic acid (540 mg) as a pale yellow syrup. To a solution of the carboxylic acid in ether (5 mL) was added an etheral solution of diazomethane until the yellow color of the solution was retained. The mixture was stirred at 0 °C for 50 min, and excess diazomethane was removed by warming the mixture to room temperature. The mixture was concentrated in vacuo, and the residue was chromatographed on a silica gel column (30 g, AcOEt/hexane (1:10)). The fraction corresponding to R_f 0.63 (AcOEt/hexane (1:2)) was concentrated in vacuo to give **7** (405 mg, 68% from **4**) as a colorless syrup. **7**: $[\alpha]^{25.5}_D$ +24.1° (*c* 1.19); IR ν^{neat}_{max} 2980, 2940, 2880, 1760, 1730, 1460, 1440, 1380, 1370, 1290, 1250, 1215, 1170, 1145, 1085 cm^{-1}; ^{1}H NMR (90 MHz) δ 0.84 (s, 3 H, CH_3-3), 0.96 (t, 3 H, *J* = 8 Hz, CH_3CH_2-3), 1.30, 1.48 (each s, each 3 H, $C(CH_3)_2$), 1.41–2.03 (m, 2 H, CH_3CH_2-3), 3.73 (s, 3 H, $COOCH_3$), 4.16 (d, 1 H, *J* = 4 Hz, H-4), 4.31 (s, 1 H, H-2), 5.82 (d, 1 H, *J* = 4 Hz, H-5). Anal. Calcd for $C_{12}H_{20}O_5$: C, 59.00; H, 8.25. Found: C, 58.83; H, 8.04.

(2*S*,3*R*,4*R*,5*R*)-3-Ethyl-4,5-(isopropylidenedioxy)-3-methyltetrahydrofuran-2-methanol (8). From 6. Compound **4** (99 mg) was converted into a TLC-homogeneous **6** (72.5 mg) as described in the preparation of **7**. To a solution of **6** (72.5 mg, 0.34 mmol) in methanol (3 mL) was added sodium borohydride (19.5 mg, 0.52 mmol), and the mixture was stirred for 40 min. The mixture was neutralized by addition of Amberlite IR-120 (H^+). The resin was removed by filtration, and the filtrate was concentrated in vacuo. The residue was chromatographed on a silica gel column (4 g, AcOEt/hexane (1:3)) to give **8** (61 mg, 81%) as a colorless syrup. **8**: TLC R_f 0.38 (AcOEt/hexane (1:2)); $[\alpha]^{25.5}_D$ +37.8° (*c* 0.91); IR ν^{neat}_{max} 3450, 2970, 2880, 1455, 1380, 1370, 1310, 1250, 1215, 1170, 1150, 1080, cm^{-1}; ^{1}H NMR (400 MHz) δ 0.81 (s, 3 H, CH_3-3), 0.95 (t, 3 H, *J* = 7.3 Hz, CH_3CH_2-3), 1.31, 1.52 (each s, each 3 H, $C(CH_3)_2$), 1.26, 1.70 (each dq, each 1 H, *J* = 14.2, 7.3 Hz, CH_3CH_2-3), 2.03 (br, 1 H, OH), 3.62 (dd, 1 H, *J* = 11.7, 3.4 Hz, CH_2OH), 3.68 (dd, 1 H, *J* = 11.7, 7.3 Hz, CH_2OH), 3.94 (dd, 1 H, *J* = 7.3, 3.4 Hz, H-2), 4.17 (d, 1 H, *J* = 3.4 Hz, H-4), 5.79 (d, 1 H, *J* = 3.4 Hz, H-5); ^{13}C NMR (100 MHz) δ 8.95 (q), 15.85 (q), 24.85 (t), 26.36 (q), 26.85 (q), 47.36 (s), 62.01 (t), 85.21 (d), 86.93 (d), 104.13 (d), 117.72 (s). Anal. Calcd for $C_{11}H_{20}O_4$: C, 61.09; H, 9.32. Found: C, 61.02; H, 9.14.

From 7. To a solution of **7** (38 mg, 0.16 mmol) in dry THF (2 mL) was added lithium aluminum hydride (12 mg, 0.31 mmol), and the suspension was stirred for 1 h. Water (0.1 mL) was added, and resulting solids were removed by filtration. The filtrate was diluted with water (15 mL) and extracted with CH_2Cl_2 (25 mL × 3). The combined extracts were dried over Na_2SO_4 and concentrated in vacuo. The residue was chromatographed on a silica gel column to give **8** (31 mg, 87%), which was identical with an authentic sample described above in all respects (TLC, $[\alpha]_D$, IR, ^{1}H and ^{13}C NMR).

Diastereomeric Mixture of (2*S*,3*S*,4*R*,5*RS*)-Methyl 3-Ethyl-4,5-dihydroxy-3-methyltetrahydrofuran-2-carboxylates (9). A solution of **7** (135 mg, 0.55 mmol) in 60% aqueous CF_3COOH (6 mL) was stirred for 7 h. After neutralization with 2 M NaOH solution, the solution was extracted with AcOEt (70 mL × 5). The combined extracts were dried over Na_2SO_4 and concentrated in vacuo. The residue was purified by repeated chromatography on a silica gel [(1) 4 g, AcOEt/hexane (1:1); (2) 4 g, AcOEt/hexane (1:2)] to give **9** (92 mg, 82%) as white crystals. **9**: TLC R_f 0.47 (AcOEt/hexane (1:2)); mp 69–71 °C; IR $\nu^{CHCl_3}_{max}$ 3410, 2970, 2880, 1735, 1460, 1435, 1380, 1360, 1280, 1230, 1210, 1140, 1090 cm^{-1}; ^{1}H NMR (90 MHz) δ 0.89 (s, 3 H, CH_3-3), 0.98 (t, 3 H, *J* = 7 Hz, CH_3CH_2-3), 0.89–1.11 (m, 1 H, OH), 1.28–2.02 (m, 3 H, CH_3CH_2-3, OH), 3.76 (s, 3 H, $COOCH_3$), 3.81, 4.00 (each d, total 1 H, each *J* = 4 Hz, H-4), 4.37, 4.47 (each s, total 1 H, H-2), 5.65, 5.79 (each d, total 1 H, *J* = 4 Hz, H-5). Anal. Calcd for $C_9H_{16}O_5$: C, 52.93; H, 7.90. Found: C, 52.77; H, 7.73.

(3*S*,4*S*)-Dihydro-4-ethyl-3-hydroxy-4-methyl-2(3*H*)-furanone (1). To a stirred solution of **9** (82 mg, 0.40 mmol) in methanol (3 mL) was added an aqueous solution (0.5 mL) of sodium periodate (103 mg, 0.48 mmol). The mixture was stirred for 30 min and then diluted with saturated aqueous NaCl solution (40 mL). This was extracted with CH_2Cl_2 (60 mL × 3). The combined extracts were dried over Na_2SO_4 and concentrated in vacuo to give crude (2*S*,3*R*)-methyl 3-formyl-2-(formyloxy)-3-methylpentanoate (**10**) (81 mg) as a colorless syrup. **10**: TLC R_f 0.69 (AcOEt/hexane (1:2)); ^{1}H NMR (90 MHz) δ 0.89 (t, 3 H, *J* = 7 Hz, H-5,5′,5″), 1.15 (s, 3 H, CH_3 at C-3), 1.68 (q, 2 H, *J* = 7 Hz, H-4,4′), 3.80 (s, 3 H, $COOCH_3$), 5.28 (s, 1 H, H-2), 8.08 (s, 1 H, OCHO), 9.53 (s, 1 H, CHO).

To a stirred solution of **10** (81 mg) in methanol (3 mL) was added sodium borohydride (7 mg, 0.19 mmol). The mixture was stirred for 30 min at 0 °C and then at room temperature for 1 h. The solution was neutralized by addition of Amberlite IR-120 (H^+). The resin was removed by filtration, and the filtrate and methanolic washings were combined and concentrated in vacuo. The residue was chromatographed on a silica gel column (3 g, AcOEt/hexane (1:4)). The fraction corresponding to R_f 0.33 (AcOEt/hexane (1:2)) was concentrated in vacuo to give **1** (38.5 mg, 66%) as a colorless syrup. **1**: $[\alpha]^{20}_D$ +3.5° (*c* 0.48), $[\alpha]^{20}_{546}$ +5.6° (*c* 0.48), $[\alpha]^{20}_{365}$ +46.0° (*c* 0.48); CD curve (MeOH) $[\theta]_{221}$ +11 150 (max); IR ν^{neat}_{max} 3430, 2970, 2930, 2880, 1770, 1480, 1460, 1420, 1380, 1340, 1320, 1210, 1190, 1170, 1110, 1000 cm^{-1}; ^{1}H NMR (400 MHz) δ 0.92 (t, 3 H, *J* = 7.3 Hz, CH_3CH_2-4), 1.19 (s, 3 H, CH_3-4), 1.41–1.57 (m centered at δ 1.50, 2 H, CH_3CH_2-4), 3.57 (br s, 1 H, OH), 3.87 (d, 1 H, *J* = 9.3 Hz, H-5), 4.17 (s, 1 H, H-3), 4.20 (d, 1 H, *J* = 9.3 Hz, H-5′); ^{13}C NMR (100 MHz) δ 8.32 (q, CH_3CH_2-4), 20.94 (q, CH_3-4), 24.15 (t, CH_3CH_2-4), 43.56 (s, C-4), 73.75 (t, C-5), 75.84 (d, C-3), 178.15 (s, C-2). Anal. Calcd for $C_7H_{12}O_3$: C, 58.32; H, 8.39. Found: C, 58.04; H, 8.21.

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Registry No. **1**, 108865-89-0; **3**, 103516-20-7; **4**, 115142-26-2; **5**, 115142-27-3; **6**, 115142-28-4; **7**, 115142-30-8; **7** acid, 115142-29-5; **8**, 115142-31-9; **9** (α isomer), 115142-32-0; **9** (β isomer), 115142-33-1; **10**, 115142-34-2.

Stereospecific Synthesis of (*Z*)- and (*E*)-Diethyl (3,3,3-Trifluoro-1-propenyl)phosphonate

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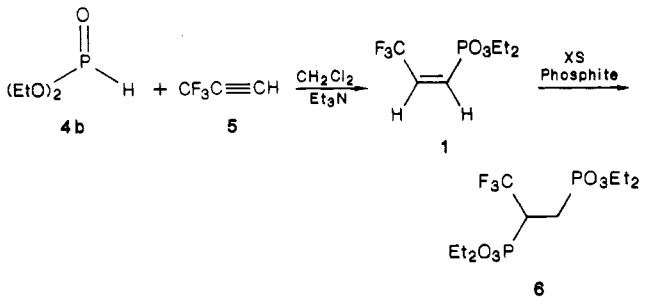
Aliphatic phosphonates have been used as isosteric substitutes for phosphate in numerous studies on biologically relevant systems.[1] Often, the preparation of these target molecules presents a formidable challenge to the

(1) Mazur, A.; Tropp, B. E.; Engel, R. *Tetrahedron* **1984**, *40*, 3949–56.

0022-3263/88/1953-3870$01.50/0

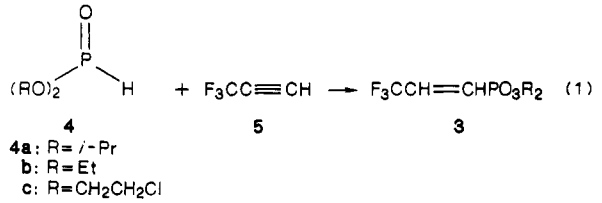
Scheme I



synthetic chemist. Indeed, the task can be even more severe when one requires a fluorine-containing substituent. As a part of an ongoing program in organophosphorus chemistry, we have developed simple, stereospecific syntheses of both (*Z*)- and (*E*)-diethyl (3,3,3-trifluoro-1-propenyl)phosphonate (**1** and **2**). The ready availability of these two synthons should provide an efficient entry into complex organic systems possessing both the trifluoromethyl and phosphonic acid moieties.

Results and Discussion

One literature reference[2] to **3** was found initially, which merely reported that a product of general formula **3a** was obtained from the action of phosphite **4a** with trifluoropropyne **5** under undisclosed conditions (eq 1). No



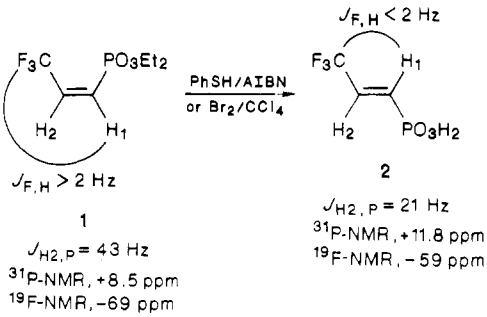
spectral data were given and the product was characterized by only elemental analysis and boiling point.

In our hands, **4b** did not react with **5** in solvent (THF or CH_2Cl_2) or neat at temperatures up to 120 °C. Similarly, free-radical initiation failed to effect any reaction. But, when the reagents were warmed together with triethylamine, a vigorous exotherm ensued at ~60 °C, resulting in a black tar. Distillation followed by chromatography gave a very low yield of **1**, which was characterized by NMR (^1H, ^{13}C, ^{31}P, and ^{19}F), IR, and mass spectra.

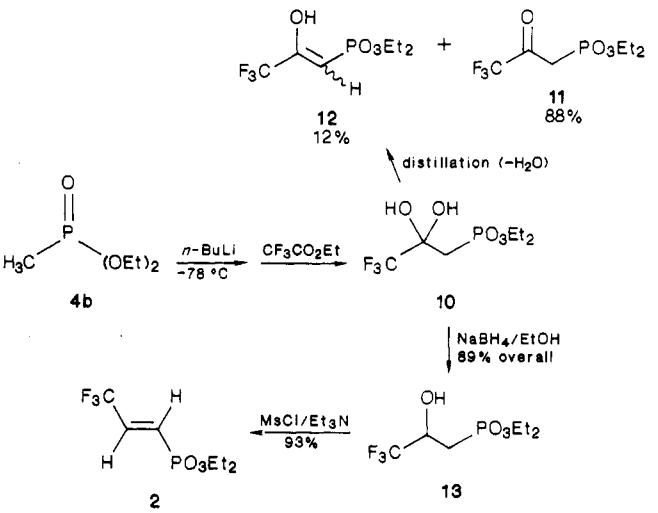
While attempting to improve the preparation of **1**, it was important to control the stoichiometry since **6** was produced in 30% yield when excess phosphite was used (Scheme I). When the reaction was run with 1 equiv of **4b**, 2 equiv of **5**, and 10 wt % of triethylamine (based on **4b**), no **6** was obtained. Use of a water-cooled autoclave and dilution with CH_2Cl_2 controlled the exotherm such that we obtained a 35% yield of 96% pure **1** simply by Kugelrhor distillation of the crude. This procedure was also applicable to the preparation of analogue **3c** in 23% yield, which has the *Z* configuration.

Characterization of **1** and assignment of the *Z* configuration was based on the large coupling between H-2 and P of 43 Hz[4] and the fact that **1** isomerized completely to

Scheme II



Scheme III



the *E* olefin in the presence of either thiophenol/AIBN/CCl_4 or Br_2 in CCl_4 (Scheme II). The product, **2**, was shown to have a $J_{H-2,P}$ = 21 Hz. In both instances, no addition products were seen. Finally, careful examination of the crude product by GLC revealed that **1** was formed in >99% stereospecificity. In fact, only 2.7% **2** in crude **1** was observed once when the exotherm reached 220 °C.

The extensive work of Truce[5] and studies describing the configurational stability of vinyl anions[6] offer a good rationale for the high stereospecificity of this process. On the basis also of the fact that others[7,8] have studied the addition of amines and alcohols to **5** with similar stereo- and regiospecificities, we favor a mechanism that involves a nucleophilic additon[9] of phosphite to give an anionic intermediate of fixed configuration which upon protonation generates **1**.

Though **2** was made via the radical isomerization of **1**, a higher yielding route was sought. Several methods based on the addition of organometallics to fluoral[10] were explored without success. The condensation of lithium diethyl methylphosphonate (**8**)[11] with ethyl trifluoroacetate[12]

(2) Gazieva, N. I.; Shchekotikhim, A. I.; Ginsburg, V. A. *Z. Obsch. Khim. (Engl. Transl.)* **1968**, *38*, 651.

(3) A note of caution is worthy here since we observed on one run that, without cooling, the pressure rose to 800 psi and the exotherm generated a temperature of 220 °C.

(4) Kenyon, G. L.; Westheimer, F. H. *J. Am. Chem. Soc.* **1966**, *88*, 3557–65.

(5) Truce, W. E.; Tichenor, G. J. W. *J. Org. Chem.* **1972**, *37*, 2391.

(6) Miller, S. F. *Adv. Phys. Org. Chem.* **1968**, *6*, 185.

(7) Raunio, E. K.; Frey, T. G. *J. Org. Chem.* **1971**, *36*, 345.

(8) Haseldine, R. N.; Leedham, K. *J. Chem. Soc.* **1952**, 3483.

(9) For a good review on nucleophilic addition of alkynes, see: Dickstein, J. I.; Miller, S. I. In *The Chemistry of the Carbon–Carbon Triple Bond*; Patai, S., Ed.; Wiley: New York, 1978; Part 2, pp 813–956.

(10) Ishikawa, N.; Koh, M. G.; Kitazume, T.; Choi, S. K. *J. Fluorine Chem.* **1984**, *24*, 419.

(11) Aboujaoude, E. E.; Collignon, N.; Savignac, P. *J. Organomet. Chem.* **1984**, *264*, 9–17.

(9) cleanly gave **10**,[13] which was expected to form a stable hydrate.[12,14] Upon distillation, **10** could be dehydrated to give **11** and **12** as an 88:12 ratio (Scheme III). For our purposes, it was better to use crude **10**, which was reduced to **13** in 89% yield after distillation. Then, **13** was converted into **2** by a one-pot mesylation/elimination in 93% yield (Scheme III).

In conclusion, we have developed stereospecific syntheses of the unique fluorinated vinylphosphonates **1** and **2** applicable to multigram scale without requiring chromatography. Our synthetic route to **2** is similar to that developed by others[15,16] who have prepared a variety of trifluoromethylated olefins. We hope to demonstrate the utility of **1** and **2** in preparing complex organophosphonic esters bearing a pendant trifluoromethyl group.[17]

Experimental Section

All ^1H NMR spectra were taken at 60, 300, or 360 MHz. The ^{13}C spectra were taken at 90.8 MHz while ^{19}F and ^{31}P NMR were run at 56.4 and 40 MHz, respectively. The ^{31}P and ^{19}F NMR were referenced to 85% H_3PO_4 and $CFCl_3$o as external standards. Infrared spectra were run on a Perkin-Elmer 781 infrared spectrophotometer. Solvents used were reagent grade, and anhydrous THF was purchased from Aldrich Chemical Co. Preparative TLC was performed with a Chromatron and plates made from Kieselgel 60 PF_{254}. Column chromatography used silica gel 60 (70–230 mesh).

(*Z*)-(3,3,3-Trifluoropropenyl)phosphonic Acid Diethyl Ester (1). A 300-mL Parr reactor, cooled to −78 °C, was charged with diethyl phosphonite **(4b)** (70 g, 0.5 mol), triethylamine (7 g, 0.07 mol), trifluoropropyne (110 g, 1.17 mol), and CH_2Cl_2 (50 mL). The reactor was sealed and attached to cooling water.[3] Stirring was started as the reactor was brought slowly to 55 °C. Pressure and temperature were both monitored externally as the pressure rose to 105 psi at 68 °C. The reaction was maintained at ~70 °C for 3 h when it was cooled to room temperature. Volatiles were vented and the contents were transferred to a round-bottom flask, concentrated, and Kugelrohr distilled at 100 °C (2.5 mm) to give 39.8 g of 96% pure **1**. An analytically pure sample could be obtained by chromatography on silica gel with 1:1 ethyl acetate/cyclohexane as eluent: ^1H NMR ($CDCl_3$) δ 1.35 (t, J = 7 Hz, 6 H), 4.25 (p, J = 7 Hz, 4 H), 6.35 (dd, J = 14.2, 12.2 Hz, 1 H), 6.47 (ddq, J = 43, 14.2, 8 Hz, 1 H); ^{31}P NMR ($CDCl_3$) δ +8.5; ^{19}F NMR ($CDCl_3$) δ −68.9 (dd, Jj = 8, 4 Hz); IR (neat) 1640, 1150, 1050, 670 cm^{-1}; MS (CI) 233 (M + 1, 100). Anal. Calcd for $C_7H_{12}F_3O_3P$: C, 36.22; H, 5.22; P, 13.34. Found: C, 35.67; H, 5.36; P, 13.50.

(3,3,3-Trifluoropropenyl)phosphonic Acid Bis(2-chloroethyl) Ester (3c). The experimental procedure for **1b** could be followed to give a 23% yield on a 0.28-mol scale **(5)**; Kugelrohr distilled at 130 °C (0.4 mm): ^1H NMR ($CDCl_3$) δ 3.75 (m, 4 H), 4.35 (m, 4 H), 6.4 (dd, J = 14, 12 Hz, 1 H), 6.5 (ddq, J = 42, 14, 8 Hz, 1 H); ^{31}P NMR ($CDCl_3$) δ +9.6; ^{19}F NMR ($CDCl_3$) δ −70.6 (dd, J = 8, 4 Hz). Anal. Calcd for $C_7H_{10}Cl_2F_3O_3P$: C, 27.91; H, 3.32; Cl, 23.59; P, 10.30. Found: C, 27.78; H, 3.50; Cl, 23.29; P, 10.55.

[1-(Trifluoromethyl)-1,2-ethanediyl]bisphosphonic Acid Tetraethyl Ester (6). The experimental procedure for **1b** was followed except that the stoichiometric ratio of phosphite **(4b)** to **5** was 2:1. The reaction was allowed to stir overnight after cooling to room temperature to give a 30% yield of **6** on a 0.01-mol scale **(5)** as a viscous oil, which was purified by column chromatography on silica gel with ethyl acetate as eluent: ^1H NMR (acetone-d_6) δ 1.35 (m, 12 H), 2.4 (m, 2 H), 3.2 (m, 1 H), 4.2 (m, 4 H); ^{31}P NMR (acetone-d_6) δ +26.0 (d, J = 36.6 Hz), +18.0 (dq, J = 36.6, 9.7 Hz); ^{19}F NMR (acetone-d_6) δ −68.1 (dd, J = 9.7, 8 Hz); MS (EI) 370.85 (M$^+$, 37.5), 369.93 (M − 1, 67.1), 324.9 (M − 46, 100), 232.95 (M − 138, 100). Anal. Calcd for $C_{11}H_{23}F_3O_6P_2$: C, 35.68; H, 6.22; P, 16.76. Found: C, 35.48; H, 6.38; P, 16.96.

(3,3,3-Trifluoro-2,2-dihydroxypropyl)phosphonic Acid Diethyl Ester (10). A dry flask, equipped with a mechanical stirrer, low-temperature thermometer, and dropping funnel that had been dried and flushed with N_2, was charged with *n*-butyllithium (0.11 mol) in hexane and THF (100 mL) at −78 °C. Diethyl methylphosphonate (15 g, 0.098 mol) was added as a solution in THF (40 mL) at a rate such that the reaction temperature never exceeded -70 °C. Upon complete addition, the anion was stirred for 10 min when ethyl trifluoroacetate (15.5 g, 0.11 mol) was added as a solution in THF (20 mL) at a rate such that the temperature did not exceed −50 °C. The cooling bath was removed after 10 min and the slightly colored solution was brought to −20 °C when 6 N HCl (25 mL) was added. The reaction mixture came quickly to room temperature, and the layers were separated. The aqueous layer was washed with ether (1 × 100 mL), and the organics were combined, dried ($MgSO_4$), filtered, and concentrated to 24 g of a yellow oil. Kugelrohr distillation at 110 °C/1 mmHg gave 16.1 g (67%) of pure **11**: ^1H NMR ($CDCl_3$) δ 1.37 (t, J = 7 Hz, 6 H), 3.50 (d, J = 23 Hz, 2 H, keto form **11**), 4.3 (p, J = 7 Hz, 4 H), 5.13 (d, J = 8 Hz, 1 H, enol form **12**), and the hydrate methylene absorbs at 2.35 (d, J = 20 Hz); ^{19}F NMR ($CDCl_3$) δ -77.1 (d, J = 2 Hz, enol **12**), -79.4 (s, keto **11**), and the hydrate absorbs at -87.5 (d, J = 2 Hz); ^{31}P NMR ($CDCl_3$) δ +15.7 (keto form **11**), +22.1 (enol form **12**), and hydrate absorbs at +26.7 ppm. Analysis was obtained on the hydrate, **10**. Anal. Calcd for $C_7H_{14}F_3O_5P$: C, 31.58; H, 5.26; P, 11.65. Found: C, 31.79; H, 5.30; P, 11.51.

(3,3,3-Trifluoro-2-hydroxypropyl)phosphonic Acid Diethyl Ester (13). The condensation described for **10** was done on a 0.5-mol scale and the crude, yellow oil obtained (125 g) was dissolved in 1:1 ethanol/H_2O (600 mL) at 0 °C. In portions, $NaBH_4$ (10.5 g, 0.27 mol) was added, evidencing a vigorous reaction. Upon complete addition, the cloudy solution was stirred for 30 min, diluted with brine (1.2 L), and extracted with ether (3 × 1 L). The ethers were combined, washed with brine (1 × 500 mL), dried ($MgSO_4$), filtered, and concentrated to give 125 g of a crude oil. Distillation then gave 111 g (89%) of a colorless liquid: bp 100 °C (0.25 mm); ^1H NMR ($CDCl_3$) δ 1.3 (t, J = 7 Hz, 6 H), −2.12 (m, 2 H), 4.1 (p, J = 7 Hz, 4 H), 4.4 (m, 1 H), 5.2 (br, 1 H); ^{31}P NMR ($CDCl_3$) δ +27.4; ^{19}F NMR ($CDCl_3$) δ −83.7 (dd, J = 6, 2 Hz). Anal. Calcd for $C_7H_{14}F_3O_4P$: C, 33.61; H, 5.64. Found: C, 33.73; H, 5.69.

(*E*)-(3,3,3-Trifluoropropenyl)phosphonic Acid Diethyl Ester (2). A solution of **13** (75 g, 0.3 mol) and triethylamine (80 g, 0.80 mol) in CH_2Cl_2 (800 mL) and cooled to 0 °C was treated with MsCl (45 g, 0.4 mol) dissolved in CH_2Cl_2 (200 mL). Addition was done at a rate such that the temperature never exceeded 20 °C. Upon complete addition, the ice bath was removed and the reaction was stirred for 17 h at room temperature. The final mixture was diluted with ether (2 L) and washed with H_2O (1 × 800 mL) and 10% HCl (1 × 800 mL). The organic was dried ($MgSO_4$), filtered, and concentrated to a dark liquid, which, when distilled, gave 65 g (93%) of a colorless liquid: bp 50 °C (0.5 mm); ^1H NMR ($CDCl_3$) δ 1.35 (t, J = 7 Hz, 6 H), 4.15 (p, J = 7 Hz, 4 H), 6.31 (ddq, J = 17.2, 15.2, 1.9 Hz, 1 H), 6.47 (ddq, J = 21.2, 17.2, 5.9 Hz, 1 H); ^{31}P NMR ($CDCl_3$) +11.8; ^{19}F NMR ($CDCl_3$) δ −59.2 (dbrd, J = 8 Hz); IR (neat) 1650, 1150, 1040 cm^{-1}; MS (CI) 233 (MH, 100). Anal. Calcd for $C_7H_{12}F_3O_3P$: C, 36.22; H, 5.22. Found: C, 36.21; H, 5.17.

Registry No. 1, 115162-55-5; **2**, 115162-56-6; **3c**, 115162-57-7; **4b**, 762-04-9; **4c**, 115162-58-8; **5**, 661-54-1; **6**, 115162-59-9; **10**, 115162-60-2; **11**, 85234-36-2; **12**, 115162-61-3; **13**, 115162-62-4; diethyl methylphosphonate, 683-08-9; ethyl trifluoroacetate, 383-63-1.

(12) The bis(dimethylphosphonamide) of **10** was prepared in 8.7% yield by this route: Ridge, J. A.; Roberts, M. F.; Schaffer, M. H.; Stark, G. R. *J. Biol. Chem.* **1976**, *251*, 5966.

(13) This compound has recently been described in the literature and is reported as its keto form: Sturtz, G.; Clement, J. C. *Polym. Bull. (Berlin)* **1983**, *9*, 125; *Chem. Abstr.* **1983**, *98*, 143947*y*. Sampson, P.; Hammond, G. B.; Weiner, D. F. *J. Org. Chem.* **1986**, *52*, 4342. On the basis of our work and careful examination of their experimentals, it is evident that both authors obtained the hydrate (**10**) and they report ^{31}P shifts consistent with this assignment.

(14) Husted, D. R.; Ahlbrecht, A. H. *J. Biol. Chem.* **1952**, *74*, 5422.

(15) Yamazaki, T.; Ishikawa, N. *Chem. Lett.* **1985**, 889.

(16) Ogoshi, H.; Mizushima, H.; Toi, H.; Aoyama, Y. *J. Org. Chem.* **1986**, *51*, 2366 and references cited therein.

(17) Nickson, T. E., paper submitted.

(18) Careful control of the temperature was crucial.[11] If the deprotonation were done at >−50 °C, a serious yield loss was obtained.