

Reactions Involving Fluoride Ion. Part 27.¹ Reactions of Perfluoro-3,4-dimethylhex-3-ene with Carbon Nucleophiles

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Reaction of methyl- and ethyl-lithium with perfluoro-3,4-dimethylhex-3-ene (1) gives products arising from nucleophilic attack with allylic displacement of fluorine from both CF₃ and CF₂ positions. Phenylmagnesium bromide gives biphenyl *via* a process which appears to involve one-electron transfer to (1). Enolate anions undergo substitution in (1) with concomitant cyclisation to give fluorinated pyran derivatives.

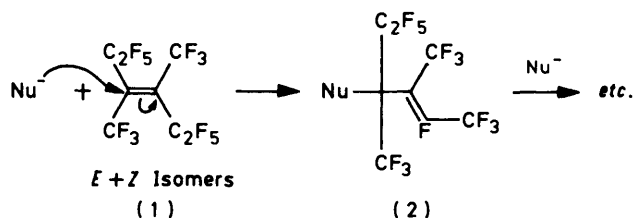
In earlier parts of this series^{2,3} we described reactions of oxygen- and nitrogen-centred nucleophiles with perfluoro-3,4-dimethylhex-3-ene (1), a tetramer of tetrafluoroethylene obtained by fluoride-induced oligomerisation. We observed interesting reactions involving initial nucleophilic attack accompanied by allylic displacement of fluoride ion (2). Here we extend these investigations to include various carbon nucleophiles.

Compound (1) reacted vigorously with methyl-lithium in ether at 0 °C and, using approximately equimolar quantities of reagents, three products (3)–(5) were identified, together with a fourth component C₁₀F₁₄H₆ which was not obtained pure but was probably derived from (4) by further reaction with methyl-lithium. Structures of compounds (3)–(5) followed in a straightforward way, from spectroscopic data. In a similar reaction, butyl-lithium in ether reacted with (1) to give a mixture of (6) and (7), identified by spectroscopic analysis.

Compounds (4) and (7) were converted into compounds (3) and (6), respectively, by reaction with potassium or caesium fluoride and it is clear, therefore, that (4) and (7) are the products of kinetic control while (3) and (6) are the products of thermodynamic control. It is well known that the C–F bond strength increases with the number of fluorine atoms attached to carbon⁴ and, therefore, it is usual for elimination of fluoride to occur preferentially from a difluoromethylene, rather than a trifluoromethyl site. The formation of (4) and (7) is, therefore, very unusual except for the structure of the hexamer formed in the fluoride-ion induced oligomerisation of tetrafluoroethylene.⁵ If both *syn*-addition of alkyl-lithium to (1) and *syn*-elimination of lithium fluoride from the resultant carbanion is assumed, probably *via* a concerted process involving both of these steps, then models clearly indicate that the formation of (4) and (7) involves much less crowding than would arise in corresponding elimination from a difluoromethylene position. The assumption of *syn*-addition and -elimination in this rationale is not unreasonable, bearing in mind the relatively low solvating power of the medium. Lithium fluoride formed in the reactions is obviously inadequate for promoting the isomerisation of (4) and (7).

Reaction of (1) with phenylmagnesium bromide led to a strikingly different process from any observed so far in reactions of nucleophiles with (1). A high yield of biphenyl was formed, together with a product which is consistent with the structure (8). However, a significant amount of the fluorine in the starting material (1) was recovered as inorganic fluoride and the formation of biphenyl in such high yield indicates a one-electron transfer in the first step, as illustrated in Scheme 1.

Heterocyclic compounds have been formed previously from (1) by reaction with bifunctional oxygen nucleophiles²



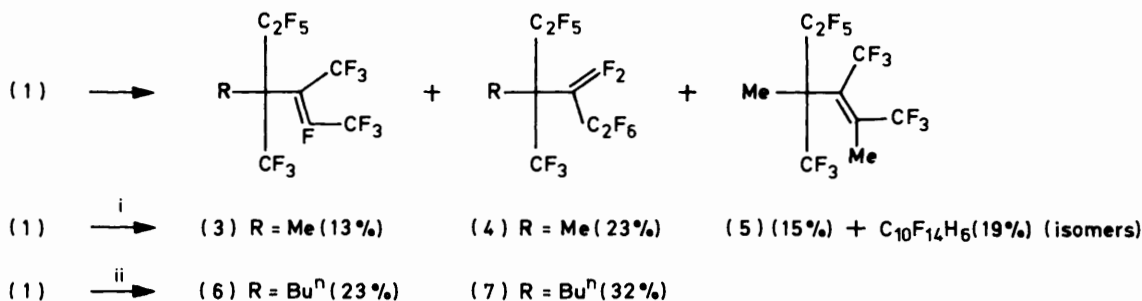
and, therefore, formation of heterocycles by reaction of (1) with enolate anions seemed highly likely by the process outlined in Scheme 2.

We expected that initial reaction would occur preferentially through carbon [structure (9)], *i.e.* the softer site,⁶ and that cyclisation by further reaction with base would occur through oxygen, giving (10)–(12). Cyclisation through carbon would be a very unfavourable process.⁷ In contrast to the reactions of (1) with alkyl-lithiums described earlier, initial attack occurs exclusively with allylic displacement of fluorine from a difluoromethylene position, *i.e.* (9), rather than from trifluoromethyl, *i.e.* the more normal process.

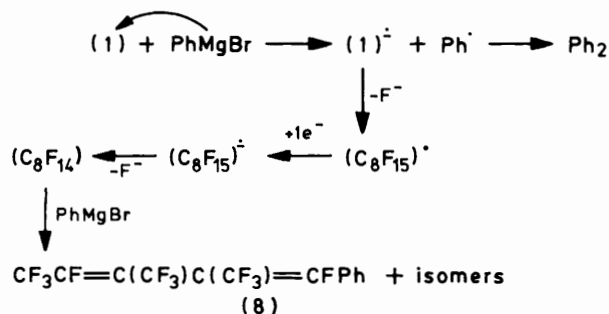
Experimental

¹⁹F N.m.r. spectra were measured using a Varian A56/60D or a Bruker HX90E spectrometer, with trichlorofluoromethane as external reference; upfield shifts are quoted as positive. Gas chromatography was carried out using columns packed with 30% silicone from rubber SE-30 on Chromosorb P (Column O) and 20% di-isodecyl phthalate on Chromosorb P (Column A). Percentage yields quoted were measured either by weighing products or by g.l.c. analysis using a gas-density balance detector. Ether refers to diethyl ether.

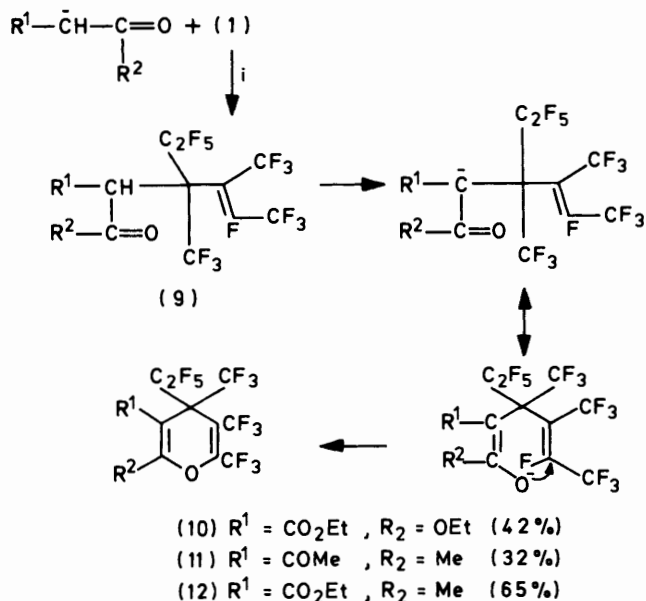
Reactions of Perfluoro-3,4-dimethylhex-3-ene (1).—(a) *With methyl-lithium.* Methyl-lithium (15 ml, *ca.* 1.7M) in ether (20 ml) was added dropwise to (1) (10.5 g, 26.3 mmol) in ether (20 ml) at 0 °C. A vigorous reaction occurred and, after addition was complete, the mixture was stirred at 0 °C for 1.6 h before it was allowed to reach room temperature. Water was added, the layers separated, and the aqueous phase was extracted with ether. The ether layer was then dried (MgSO₄) and the ether removed by distillation, leaving a residue which was transferred under vacuum (7.4 g) and which was shown by g.l.c. (column O, 90 °C), to contain four products; these were separated by preparative-scale g.l.c. (column O; 85–150 °C) and were identified as follows, in order of increasing retention times: 4-methylperfluoro-3,4-dimethylhex-2-ene (3) (13%) [Found: C, 27.2; H, 0.7; F, 71.7%; (*M* – 19)⁺ 377.



Reagents: i, MeLi, Et₂O, 0 °C. ii, BuⁿLi, hexane, 0 °C

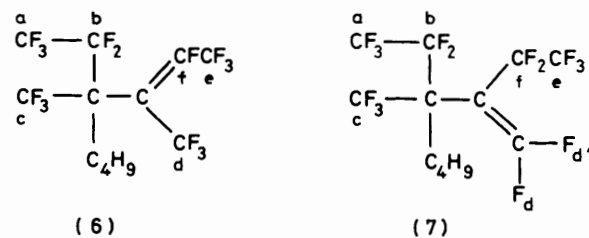
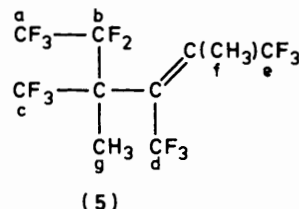
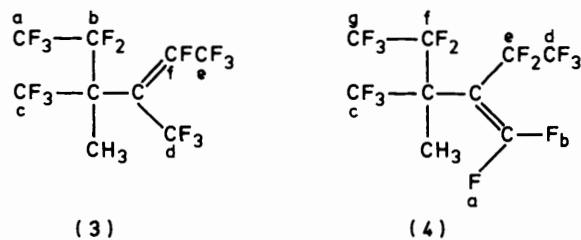


Scheme 1.



Scheme 2. Reagents: i, NaH, tetraglyme, room temp.

C₁₂H₃F₁₅ requires C, 27.3; H, 0.8; F, 71.9%; *M*, 396; δ_F, 56.7 (3F_d), 67.8 (3F_c), 69.7 (3F_e), 82.1 (3F_a), 86.4 (s, 1F_f), and 114.1 p.p.m. (2F_b) (assignments were made by reference to model compounds⁸); δ_H 1.1; 3-methylperfluoro-2-ethyl-3-methylpent-1-ene (4) (23%) (Found: C, 27.4; H, 0.7; F, 71.5%; *M*⁺, 396); δ_F, 56.7 (q, *J*_{a,c} 40 Hz, F_a), 59.6 (F_b), 71.8 (d, *J*_{a,c} 40 Hz, 3F_c), 86.5 (s, 3F_d), 88.7 (d, *J*_{d,b} 15 Hz, 3F_d), 106.6 (2F_e), and 117.6 p.p.m. (2F_f); δ_H 1.3; 2,4-dimethylperfluoro-3,4-dimethylhex-2-ene (5) (15%) (Found: C, 30.6; H, 1.4; F, 68.1%; *M*⁺, 392. C₁₀H₆F₁₄ requires C, 30.6; H, 1.5; F, 67.8%; *M*, 392);



Numbering schemes for n.m.r. assignments

δ_F 54.4 (3F_d), 63.1 (3F_e), 64.2 (3F_c), 81.2 (3F_a), and 110.2 p.p.m. (2F_b); δ_H 1.4 (m, H_a) and 1.8 (H_f); the fourth component (27%) appeared, by n.m.r., to be a mixture of isomers (Found: C, 30.4; H, 1.3; F, 67.8%; *M*⁺ 392. Calc. for C₁₀H₆F₁₄: C, 30.6; H, 1.5; F, 67.8%; *M*, 392). We were unable to proceed further in structure elucidation.

A portion of the crude product (1 g) from the reaction described above, and potassium fluoride (0.12 g) in tetraglyme, was stirred for 4 days at room temperature. Analysis by g.l.c. (column O; 95–100 °C) showed that (3) became the major component under these conditions, rather than (4) which was the major component in the original mixture.

(b) With *n*-butyl-lithium. Compound (1) (8 g, 20 mmol) in dry ether (15 ml) was cooled to 0 °C and *n*-butyl-lithium (12 ml, ca. 20 mmol) in hexane was added during 0.5 h. The mixture was slowly allowed to reach room temperature and water was added. The organic layer was separated, dried (MgSO₄) and solvent was removed by distillation. Analysis of the residue (4.8 g) by g.l.c. (column O; 100 °C) showed two components that were separated by preparative-scale g.l.c. to give 4-butylperfluoro-3,4-dimethylhex-2-ene (6) [Found:

(*P* - 21) 417; Calc. for $C_{12}H_9F_{15}$: *M*, 438]; δ_F 53.9 (3F_a), 61.3 (3F_c), 69.6 (3F_e), 81.6 (3F_a), 92.6 (1F_f), and 114.9 p.p.m. (2F_b); δ_H 0.84 (overlapping m); and 3-butylperfluoro-2-ethyl-3-methylpent-1-ene (7) [Found: (*P* - 21) 417]; δ_F 55.9 (2F_{d,d'}), 60.4 (3F_c), 79.7, 80.6 (3F_a, 3F_e), 101.1, 103.6 (2F_f), and 114 p.p.m. (2F_b); δ_H 0.84 (overlapping m).

A portion (1 g) of the crude product from this reaction which contained *ca.* equal amounts of (6) and (7) was treated with potassium fluoride in tetraglyme, as described in the previous experiment. The product contained mainly (6).

Reactions of (1) with Enolate Anions.—(a) *With diethylmalonate.* Compound (1) (4.23 g, 10.6 mmol) was added to an equimolar amount of sodium diethylmalonate in tetraglyme (5 ml), and the mixture was stirred at room temperature for 16 h. Water (50 ml) was then added and the resultant oily lower layer was removed, dried (P₂O₅), and transferred under vacuum to a cold trap. This liquid (4.30 g) was shown by g.l.c. (column K) to contain starting materials and one major product (42% based on fluorocarbon consumed). A sample of this was obtained pure by preparative-scale g.l.c. (column K) and identified as 5-ethoxycarbonyl-6-ethoxy-2,3,4-tris(trifluoromethyl)-4-pentafluoroethylpyran (10) [Found: C, 34.7; H, 2.1; F, 51.2%; (*P* - C₂H₅O), 475; (*P* + 1), 521 (C.I.). C₁₅H₁₀F₁₄O₄ requires C, 34.6; H, 1.9; F, 51.2%; *M*, 520]; ν_{max} 2 990, 1 740, 1 700, and 1 630 cm⁻¹; δ_F 53.3 (m, 3F), 62.8 (m, 3F), 66.7 (q, *J* 17 Hz, 3F), 80.8 (s, 3F), and 113.3 p.p.m. (m, 2F); δ_H 1.33 (m, 6 H) and 4.33 (m, 4 H).

(b) *With acetylacetone.* A similar reaction and work-up procedure using (1) (6.22 g, 15.6 mmol), acetylacetone (3.53 g, 35.3 mmol), sodium hydride (35.3 mmol), and tetraglyme (10 ml) gave 5-acetyl-6-methyl-2,3,4-tris(trifluoromethyl)-4-pentafluoroethylpyran (11) (32%) [Found: C, 33.7; H, 1.55; F, 58.1%; (*P* - CH₃) 445; (*P* - F) 441. C₁₃H₆F₁₄O₂ requires C, 33.9; H, 1.30; F, 57.8%; *M*, 460]; ν_{max} 2 920, 2 880, 1 720, 1 685, and 1 630 cm⁻¹; δ_F 54.0 (m, 3F), 62.0 (m, 3F), 67.0 (q, *J* 19 Hz, 3F), 81.3 (s, 3F), and 112.7 p.p.m. (m, 2F); δ_H 2.00 (s, 3 H) and 2.40 (s, 3 H).

(c) *With ethyl acetoacetate.* Similarly, compound (1) (12.00 g, 30.0 mmol), ethyl acetoacetate (9.1 g, 70.0 mmol), sodium hydride (70.0 mmol), and tetraglyme (20 ml) gave 5-ethoxycarbonyl-6-methyl-2,3,4-tris(trifluoromethyl)-4-pentafluoroethylpyran (12) (65%) [Found: C, 34.0; H, 1.85; F, 53.8%; (*P* - C₂H₅O), 445. C₁₄H₈F₁₄O₃ requires C, 34.3; H, 1.63; F, 54.3%; *M*, 490]; ν_{max} 2 990, 2 940, 1 740, 1 690, and 1 630 cm⁻¹; δ_F 53.7 (m, 3F), 62.7 (m, 3F), 67.2 (q, *J* 17 Hz, 3F), 81.3 (s, 3F), and 113.3 p.p.m. (m, 2F); δ_H 1.33 (t, *J* 7 Hz, 3 H), 2.13 (s, 3 H), and 4.27 (q, *J* 7 Hz, 2 H).

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