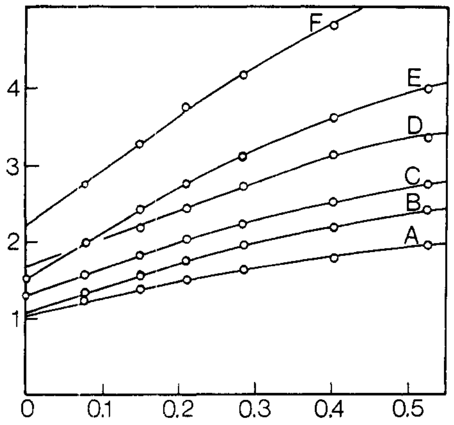

Figure 1. Observed chemical shifts with DL-sulfite ester (0.5 M solution in $DCCl_3$) in the presence of $Eu(fod)_3$: A, CH_3CH_2 trans to $=S\rightarrow O$; B, CH_3CH_2 cis to $=S\rightarrow O$; C, Me trans to $=S\rightarrow O$; D, CH_3CH_2 trans to $=S\rightarrow O$; E, Me cis to $=S\rightarrow O$; F, CH_3CH_2 cis to $=S\rightarrow O$.

reagent to a 0.5 M solution of the DL isomer in deuteriochloroform. The results are shown in Figure 1.

Of the two singlet methyl signals, the one at δ 1.50 showed a much greater chemical shift and is therefore cis to the sulfoxide group.[7] This methyl signal is the same as the methyl signal of peak number 3 which therefore must be the *E* isomer. The relative chemical shifts of the methylene and the triplet methyl signals confirm these assignments.

Experimental Section

The infrared spectra were determined with a Perkin-Elmer Model 337. The NMR spectra of the samples separated by VPC were obtained by Mr. Mark Mattingly, using a Varian XL-100; other NMR spectra were measured on a Varian EM-360. Chemical shift values are expressed as δ values downfield from tetramethylsilane internal standard. VPC separations were carried out on an F&M Model 300, using 6.3-mm diameter copper tubing 2-m long packed with the 10% F&M Versamid-900 on 60/80 mesh Diatoport-S for one column and with 20% DC silicon fluid 710 on 80/100 mesh DMCS Chromosorb-P for the other column. Elemental analyses were performed under the direction of Dr. Franz J. Kasler.

Sulfite Ester of (DL)-3,4-Dimethyl-3,4-hexanediol. To 3 g (0.021 mol) of the solid pinacol,[1] mp 50 °C, dissolved in 28 mL of pyridine and 23 mL of dry ether, was added dropwise at 15 °C with mechanical stirring 8.5 mL (0.12 mol) of thionyl chloride. After the addition, the reaction mixture was stirred for 1 h at room temperature and then poured onto ice. The ether extract was washed with water, dried ($MgSO_4$), and distilled to give 1.7 g (43% yield) of the sulfite ester: bp 67–68 °C (0.6 mm); IR (film) 3000, 2950, 2890, 1460, 1380, 1210 (S=O),[5a] 1135, 995, 885, 810, 780, 715, and 620 cm^{-1}; ^{1}H NMR ($DCCl_3$) δ 2.3–1.6 (m, 4, $-CH_2-$), 1.50 (s, 3, CH_3 cis to sulfoxide), 1.28 (s, 3, CH_3 trans to sulfoxide), 1.07 (t, 3, J = 7.3 Hz, CH_2CH_3 cis to sulfoxide), and 1.04 (t, 3, J = 7.3 Hz, CH_2CH_3 trans to sulfoxide).

Anal. Calcd for $C_8H_{16}O_3S$: C, 49.97; H, 8.39; S, 16.67. Found: C, 50.13; H, 8.53; S, 16.90.

Acknowledgment. The authors wish to thank Dr. Paul Mazzocchi for his assistance in obtaining the spectra, using the chemical shift reagent.

Registry No. DL-3,4-Dimethyl-3,4-hexanediol sulfite ester, 71076-42-1; (*E*)-*meso*-3,4-dimethyl-3,4-hexanediol sulfite ester, 71116-99-9; (*Z*)-*meso*-3,4-dimethyl-3,4-hexanediol sulfite ester, 71117-00-5; pinacol, 76-09-5.

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Synthesis and Reactions of Perfluoroneopentyllithium

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The low-temperature-gradient (LTG), direct fluorination of neopentane can synthesize *F*-neopentane (I) in yields approaching 70%.[1] Furthermore, our own research has shown that it is possible to optimize not only *F*-neopentane but also 1-hydryl-*F*-neopentane (II) and 1,3-dihydryl-*F*-neopentane (III). This development has made multigram quantities of all of these unique fluorocarbon molecules available for further research into their derivative chemistry.[2]

The metalation of compounds II or III is possible by known procedures[3,4] (eq 1); however, to our knowledge no

$$(F_3C)_3CCF_2H + RLi \rightarrow (F_3C)_3CCF_2Li + RH \quad (1)$$

$$R = CH_3,\ n\text{-Bu},\ t\text{-Bu}$$

attempt has been made to metalate so sterically crowded a system as the *F*-neopentane derivatives. Furthermore, the synthesis of the lithium derivatives provides a route for the introduction of the unique *F*-neopentyl group into existing molecules where it can be utilized as a probe group or a label or for the introduction of specific properties such as high oxygen solubility.[5,6]

Results and Discussion

F-Neopentyllithium is somewhat more thermally stable than other *F*-alkyllithium derivatives. This stability is undoubtedly due to both its inability to "β eliminate" lithium fluoride to form an olefin and the inductive effect of the *F*-*tert*-butyl group. *F*-Neopentyllithium will, however, undergo "α elimination" of lithium fluoride to form *F*-*tert*-butylfluorocarbene near 0 °C.[7] *F*-Neopentyllithium may be prepared in ethyl ether (CH_3Li) or alkane (*n*-butyl- and *tert*-butyllithium) solvents. The initial metalation in both ether and alkane is good, as measured by methane evolution or product yields, respectively, but *F*-neopentyllithium attacks the ether solvent and must be used rapidly. Routinely, in ether 20–50% of the fluorocarbon residue is recovered as 1-hydryl-*F*-neopentane. An, as yet, unidentified hydrofluorocarbon ether is recovered in addition to starting material if the ether–*F*-alkyllithium solution stands at −78 °C overnight. Virtually all the *F*-neopentyllithium is consumed on standing overnight at −78 °C. The alkane-*F*-alkyllithium solutions are much more stable. Alkanes are the solvents of choice for investigating the reactions of the carbene species generated by the α elimination of lithium fluoride.

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[1] R. J. Lagow and N. Maraschin, *Inorg. Chem.*, **12**, 1458 (1973).

[2] Compounds II and III were first reported by A. F. Maxwell, F. E. Detoro, and L. A. Bigelow, *J. Am. Chem. Soc.*, **82**, 5827 (1960). Their characterization of compound II listed mp 69 °C and mol wt 259–261.

[3] P. Dodman and J. C. Tatlow, *J. Fluorine Chem.*, 8, 263 (1976).

[4] S. F. Campbell, J. M. Leach, R. Stephens, and J. C. Tatlow, *J. Fluorine Chem.*, 1, 85 (1971).

[5] E. P. Wesseler, R. Iltis, and L. C. Clark, Jr., *J. Fluorine Chem.*, **9**, 137 (1977).

[6] D. D. Lawson, J. Moacanin, K. V. Scherer, Jr., T. F. Terranova, and J. D. Ingham, *J. Fluorine Chem.*, **12**, 221 (1978).

[7] To be published.

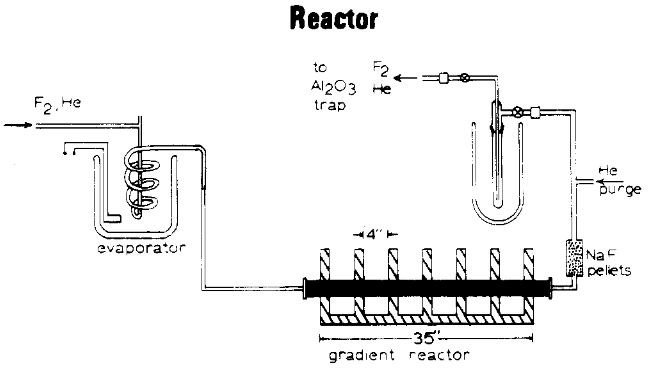

Figure 1. Low-temperature gradient (LTG) fluorination apparatus–reactor consists of a 1 in. schedule 40 nickel pipe filled with light copper turnings. The reactor is surrounded by a stainless-steel polyurethane insulated box containing six vertical wells (1–r zones 1–6). The exposed pipe ends may be insulated or heated providing shallow or sharper temperature gradients, respectively.

F-Neopentyllithium has been characterized by its reactions with elemental iodine and bromine to produce the *F*-neopentyl iodide and bromide, respectively, two previously unreported compounds.

Experimental Section

Elemental analyses were performed by Schwarzkopf Microanalytical Laboratory. ^{19}F nuclear magnetic resonance data was obtained on Varian A56-60 and Bruker WX-90 NMR spectrometers; proton spectra were obtained on a Nicolet TT-14 FT–NMR operating at 60 MHz. Infrared were of gas samples at 1 and 20 torr in 10-cm KBr cells. Mass spectra were taken on a Hewlett Packard 5934A GC/MS with a computer control data system.

In a typical preparation 1-hydryl-*F*-neopentane (2.0 mL, 1.2 g, 0.017 mol) was syringed into the evaporator of the LTG fluorinator (Figure 1), at −65 °C.[8] A 100 cm^3/m helium flow carried the vapor into the six-zone reactor (zones 2–4 and 6 at −78 °C, zone 5 at −130 °C). When the evaporator bath reached

Table I. Characterization of 1-Hydryl-*F*-neopentane

mp 73–73.5 °C (lit.[2] mp 69 °C)

mass spectra (*m*/*e*, intensity, fragment)
electron impact: 251, 0.4, $C_5F_{10}H$; 200, 2.9, C_4F_8; 181, 77.2, C_4F_7; 163, 5.0, C_4F_6H; 131, 2.9, C_3F_5; 113, 18.0, C_3F_4H; 93, 9.8, C_3F_3; 75, 3.9, C_3F_2H; 69, 100, CF_3; 51, 91.6, CF_2H

infrared: 3000 (vw) (ν_{C-H}), 1400 (w), 1363 (mw), 1302 (sh), 1275 (vs), 1250 (sh), 1215 (mw), 1183 (w), 1138 (vw), 1109 (vw), 1066 (mw), 985 (s), 790 (w), 770 (w), 743 and 727 (dm), 670 (m), cm^{-1}

^{19}F NMR (ppm vs. $CFCl_3$ 10%/$CDCl_3$) ϕ_{CF_3} 65.4 ppm (triplet of doublets, $J_{CF_3CF_2} = 10.5$ Hz); ϕ_{CF_2H} 125.7 ppm (doublet of multiplets, ~dectet, $J_{CF_3H} = 1.0$ Hz)

^1H NMR (ppm vs. Me_4Si, $CHCl_3$ 1% ≡ 7.25 ppm) δ 6.26 ppm (triplet of multiplets, $J_{CF_2H} = 53.0$ Hz)

Table II. Characterization of 1,3-Dihydryl-*F*-neopentane

mp 58–59 °C[a]

mass spectra (*m*/*e*, intensity, fragment):
electron impact: 181, 8.9, C_4F_7; 163, 100, C_4F_6H; 113, 36, C_3F_4H; 95, 15.6, $C_3F_3H_2$; 93, 9.0, C_3F_3; 75, 13.3, C_3F_2H; 69, 50.6, CF_3; 51, 76.0, CF_2H; 31, 2.8, CF

infrared: 3005 (vw) (ν_{CH}), 1390 (sh), 1370 (m), 1305 (sh), 1285 (s), 1264 (vs), 1210 (w), 1180 (m), 1160 (mw), 1090 (w), 1075–1056–1040 (tm), 981 (ms), 765 (w), 740–725–710 (mult w), 670 (w) cm^{-1}

^{19}F NMR (ppm vs. $CFCl_3$ 10%/$CDCl_3$) ϕ_{CF_3} 64.6 ppm (pentet of triplets, $J_{CF_3CF_2} = 11.0$ Hz), ϕ_{CF_2} 127.3 ppm (doublet of multiplets, ~heptet, $J_{CF_3H} = 0.8$ Hz)

^1H NMR (ppm vs. Me_4Si, $CHCl_3$ 1% ≡ 7.25 ppm) δ 6.21 ppm (triplet of multiplets, $J_{CF_2H} = 54.5$ Hz)

[a] Does not melt cleanly; tends to form glass at 25 °C; crystals wet ca. 45 °C.

Table III. Characterization of *F*-Neopentyl Iodide

mp −0.5–0.0 °C[a]

mass spectra (*m*/*e*, intensity, fragment)
electron impact: 396, 0.8, $C_5F_{11}I$; 289, 0.4, C_4F_6I; 269, 15.3, C_5F_{11}; 181, 11.1, C_4F_7; 127, 12.5, I; 69, 100.0, CF_3
chemical ionization: 377, 7.7, $C_5F_{10}I$; 269, 43.1, C_5F_{11}; 181, 13.3, C_4F_7; 177, 4.3, CF_2I; 75, 100.0, C_3F_2H; 69, 7.1, CF_3

infrared: 1285 (vs), 1270, (vs), 1220 (m), 1120 (w), 1025 (w), 988 (s), 809 (m), 751 (mw), 730 (mw), 720 (m) cm^{-1}

^{19}F NMR (ppm vs. $CFCl_3$ 10%/$CDCl_3$) ϕ_{CF_3} 63.34 ppm (triplet), ϕ_{CF_2} 42.73 ppm (dectet, $J = 10.5$ Hz)

Anal. Calcd for $C_5F_{11}I$; C, 15.17; F, 52.78; I, 32.05. Found: C, 15.30; F, 52.67; I, 31.88.

[a] Sample is colorless at the start but has a pale rose color after 10 min at −10 to 6 °C.

Table IV. Characterization of *F*-Neopentyl Bromide

mp 51.5–52.0 °C

mass spectra (*m*/*e*, intensity, fragment):
electron impact: 269, 51.9, C_5F_{11}; 243, 2.0, $C_4F_6{}^{81}Br$; 241, 2.1, $C_4F_6{}^{79}Br$; 181, 30.8, C_4F_7; 131, 42.9, $CF_2{}^{81}Br$; 129, 40.7, $CF_2{}^{79}Br$; 93, 13.4, C_3F_3; 81, 3.8, ^{81}Br; 79, 3.2, ^{79}Br; 69, 100.0, CF_3
chemical ionization: 331, 10.5, $C_5F_{10}{}^{81}Br$; 329, 10.8, $C_5F_{10}{}^{79}Br$; 269, 100.0, C_5F_{11}; 181, 21.6, C_4F_7; 131, 5.2, $CF_2{}^{81}Br$; 129, 5.3, $CF_2{}^{79}Br$; 69, 6.4, CF_3

infrared: 1290 (vs), 1280 (vs), 1225 (m), 1040 (w), 995 (s), 840 (m), 760 (w), 735 (m) cm^{-1}

^{19}F NMR (ppm vs. $CFCl_3$ 10%/$CDCl_3$) ϕ_{CF_3} 63.84 ppm (triplet), ϕ_{CF_2} 47.92 ppm (dectet, $J = 10.5$ Hz)

Anal. Calcd for $C_5F_{11}Br$; C, 17.21; Br, 22.90; F, 59.89. Found: C, 17.44; Br, 22.84; F 59.68.

0 °C (~6 h), zone 1 was filled with dry ice, F_2 at 0.5 cm^3/m was started, and the helium flow was reduced to 20 cm^3/m. Every 24 h the F_2 was increased by 0.5 cm^3/m to a maximum of 2.0 cm^3/m; the helium was reduced to 10 cm^3/m and 5 cm^3/m and then stopped; and one additional zone each 24 h was not replenished with dry ice/alcohol.[9] Zone 5 initially at -130 °C was warmed to -120, -110, and -100 °C at 24-h intervals until the liquid nitrogen dewar (Linde, LS-160) connected to the temperature controller was exhausted; it was then filled with dry ice/alcohol and not replenished in sequence. The day that zone 6 began to warm from -78 °C the helium was restarted at 5.0 cm^3/m.[10] The product was collected in a liquid-nitrogen-cooled trap, transferred to the vacuum line, and fractionated through -96 and -196 °C traps. The -96 °C fraction was dissolved in CCl_4 and separated by GLC on a Fluorosilicone QF-1, 10% on Chromosorb P column $^3/_8$ in. × 7 m long. The yields are *F*-neopentane (I), 0.32 g (6.7%), 1-hydryl-*F*-neopentane (II), 1.9 (24%), and 1,3-dihydryl-*F*-neopentane (III), 1.17 g (28%). Complete characterizations for compounds II and III are given in Tables I and II, respectively.

F-Neopentyl iodide was prepared as follows: 1-Hydryl-*F*-neopentane (0.545 g, 2.02 mmol) was dissolved in 5 mL of anhydrous ethyl ether under a nitrogen atmosphere. That solution was added dropwise to $CH_3Li/LiBr$ (3.0 mL, 4.8 mmol, 1.6 M Alfa Ventron) diluted in 5 mL of ether cooled to -50 to -55 °C. The mixture was magnetically stirred until 45 mL of gas, CH_4, had been evolved (about 2 h). A slight excess of iodine (1.27 g, ca. 5 mmol) was dissolved in 40 mL of dry ether and added to the -50 °C mixture dropwise until the iodine color persisted. The product was isolated by vacuum-line fractionalization followed by gas–liquid chromatography on Fluorosilicone QF-1, 10% on Chromosorb P, yielding *F*-neopentyl iodide (0.285 g, 35.6% yield; 48% yield based on 1-hydryl-*F*-neopentane recovered). Complete characterization is given in Table III.

F-Neopentyl bromide was synthesized and purified in an analogous way except that the bromine–ether solution was added to the reaction mixture at -78 °C. Its characterization is given in Table IV. In contrast to *F*-neopentyl iodide which slowly decomposes at room temperature, the bromide is stable indefinitely.[11]

Acknowledgment. The authors would like to acknowledge the support of the Research Corporation, Cottrell Research Fund, and the Office of Naval Research for partial support of this work. ^{19}F NMR spectra were run with the assistance of Professor Richard J. Lagow and Mr. Bob Smithwick.

Registry No. I, 374-51-6; II, 2993-15-9; III, 71076-43-2; *F*-neopentyllithium, 71076-44-3; perfluoroneopentyl iodide, 71076-45-4; perfluoroneopentyl bromide, 71076-46-5; perfluoro-2,2,5,5-tetramethylhexane, 71076-47-6.

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(8) The vapor pressure of neopentane at -65 °C is such that the helium flow carries the vapor to the reactor so that it deposits as a fine snow-like solid of high surface area. This step is very important for good yields.

(9) These steps bring about a gradually increasing concentration and quantity of fluorine, a gradually increasing temperature at a given point, and an overall temperature gradient. The temperature gradient volatilizes the more highly (75%) fluorinated species exposing less highly fluorinated species to fluorination.

(10) The dilution step at final warmup is very important in shifting the product mixture toward the mono- and dihydryl-*F*-neopentanes.

(11) The decomposition of pure *F*-neopentyl iodide is to iodine and presumably *F*-2,2,5,5-tetramethylhexane. This was deduced from the mass spectra: Chemical Ionization gave: 519, 2, $C_{10}F_{21}$, and 319, 100, C_6F_{13}. Electron Impact gave: 319, 22, C_6F_{13}; 269, 10, C_5F_{11}; 231, 47, F_5F_9; 181, 100, C_4F_7; 119, 60, C_2F_5; 69, 31, CF_3. Major peaks in the infrared spectrum (cm^{-1}) were: 1285 vs, 1270 vs, 1247 sh, 1218 m, 1182 w, 1163 mw, 1033 w, 988 s, 784 mw, 748 m, 734 m, and 707 ms. Homolytic cleavage of the C–I bond is a common reaction of *F*-alkyl iodides on photolysis or thermolysis.

2,2,6,6-Tetramethylpiperidine-*N*-oxyl-4-carboxylic Anhydride

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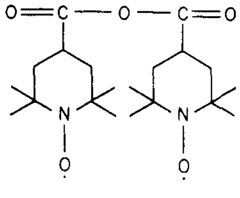
Reagents for "spin labeling" are of some interest.[1] We wish to report preparation and characterization of the title compound 1. It is: (1) easily prepared; (2) crystalline; (3) stable and easily stored under ambient conditions; (4) easily weighed and simply manipulated; (5) modestly water soluble (see below); and (6) achiral.



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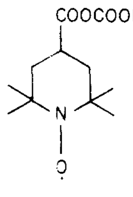
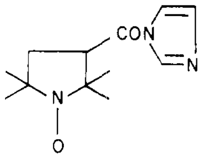


2

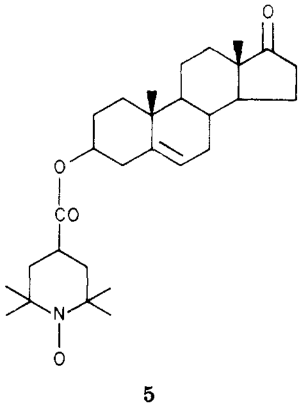
Anhydride 1 is in fact the product of a reaction described by Rauckman and Rosen,[2] who reported the preparation and in situ use of the mixed anhydride 2 as a spin acylating agent. We stumbled across 1, the actual acylating agent, as a result of investigating the influence of reagent ratios on yields in the preparation of "2".

The virtues of 1 are listed above. Its lack of chirality is in our eyes of some importance if one is contemplating spin acylation of a chiral system (e.g., proteins). This virtue is not shared by the spin acylating reagent 3 recently reported by Adackaparayil and Smith.[3]



3

Anhydride 1 reacts smoothly with primary and secondary alcohols in the presence of 4-(dimethylamino)-pyridine as catalyst.[4] Esters are formed in high yield in this fashion as is exemplified by the acylation of 3-hydroxy-17-ketoandrost-5-ene (4); the ester 5 is isolated in 93% yield.



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