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SOME APPROACHES TO THE SYNTHESIS OF FLUORINATED ALCOHOLS AND ESTERS.

II. USE OF F-ALKYL IODIDES FOR THE SYNTHESIS OF F-ALKYL ALKANOLS

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SUMMARY

Free radical addition of an F-alkyl iodide (R_FI) to an alkenol or ester, followed by appropriate reduction is an efficient method for preparing the corresponding F-alkyl-alkanols of the homologous series, $R_F(CH_2)_n$-OH. When n = 2,4 or higher, the two steps take place smoothly. The 1,2,3-substituted systems $R_FCH_2CHYCH_2Z$, however, are susceptible to surprising difficulties. Reduction of $R_FCH_2CHICH_2OH$ to $R_F(CH_2)_3OH$ by hydrogen and catalyst (strong base acid acceptor), can be done either in one step or <u>via</u> $R_FCH=CHCH_2OH$; however, dehydrohalogenation may also give the epoxide, and reduction in this case leads to the secondary alcohol, $R_FCH_2CH(CH_3)OH$. By contrast, reduction of $R_FCH_2CHICH_2OAc$ by tributyltin hydride or with hydrogen over palladium (diethylamine acid acceptor) goes smoothly. Zinc and acid reduction of $R_FCH_2CHICH_2OAc$ gives elimination to $R_FCH_2CH=CH_2$; even $R_FCH=CICH_2OH$ gives $R_FCH=C=CH_2$ besides $R_FCH=CHCH_2OH$. $R_FCH=CICH_2CH_2OH$, however, with zinc and acid is reduced cleanly to $R_FCH=CHCH_2CH_2OH$.

INTRODUCTION

Preparation of fluorine-containing alcohols is central to the study and application of fluorinated compounds in organic chemistry [1]. In the terminally-substituted series, $R_F(CH_2)_nOH$ (and esters), where R_F represents a perfluorinated or substantially fluorinated group and n is an integer of modest size, we find a number of interesting synthetic problems. Free radical additions of F-alkyl iodides (R_FI), pioneered by Haszeldine [2], have made possible the synthesis of many members of this series. For example, R_FI, when added to vinyl acetate (azonitrile initiation) [3,4], gave $R_FCH_2CHIOAc$, and this substance gave the alcohol, $R_FCH_2CH_2OH$ and ester.
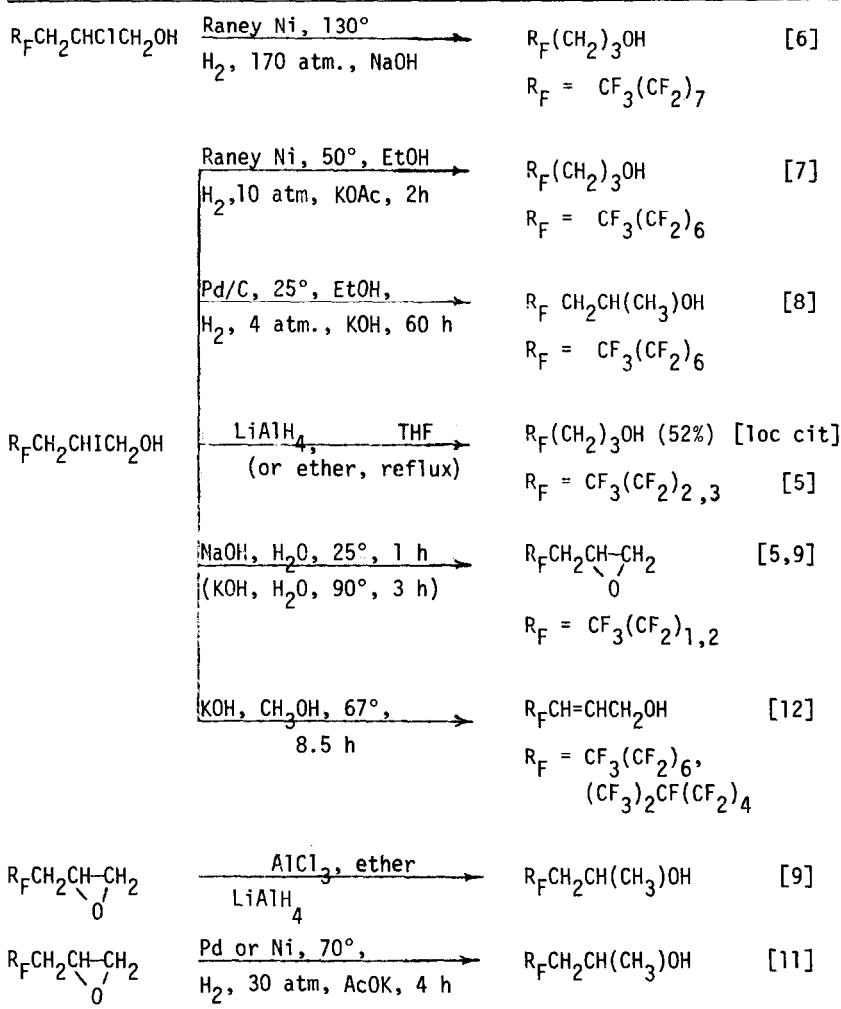
RESULTS AND DISCUSSION

Synthesis of $R_F(CH_2)_3OH$. Chart I summarizes the synthesis of $R_F(CH_2)_3OH$ and related substances from $R_FCH_2CHXCH_2OH$ (X = Cl or I), by reduction and elimination reactions. Early synthesis of $R_F(CH_2)_3OH$ utilized lithium aluminum hydride deiodination of $CF_3(CF_2)_2CH_2CHICH_2OH$ (from R_FI and allyl alcohol) [5]. Difficulties in exploiting this method will be discussed below. More recent references to the use of $LiAlH_4$ have not appeared in the literature.

Removal of iodine from $R_FCH_2CHICH_2OH$ by catalytic reduction in the presence of base has given varying results. Several workers [6,7] obtained $R_F(CH_2)_3OH$, while others [8] reported the secondary alcohol, $R_FCH_2CH(CH_3)OH$. There is a logical explanation for the differing results. Reaction of base with $R_FCH_2CHICH_2OH$ can give two different products, just as with the acetate ester [3]: the 2-alken-1-ol, $R_FCH=CHCH_2OH$ [12] or the epoxide, $R_FCH_2CH-CH_2$ [5,9,10]. Catalytic reduction of the 2-alkenol gave $R_F(CH_2)_3OH$ [6], while reduction of the epoxide gave the secondary alcohol, either using $LiAlH_4$ [5,9], or catalytically over palladium or nickel [11]. If the 2-alkenol is formed first, the product to be expected is the same $R_F(CH_2)_3OH$ that is formed by hydrogenolysis. If the epoxide is formed in the reaction system before halogen is displaced catalytically by hydrogen, the product to be expected is the secondary alcohol.

The alkenol was formed in anhydrous methanol with KOH as base [12]. The epoxide apparently was more often obtained using aqueous alkali [5,9]. A mixture of both substances may be formed under other conditions [3,4]. Understandably, then, it is with some reluctance that one would pursue the synthesis of $R_F(CH_2)_3OH$ using either the alkenol or the epoxide as a precursor.

$CF_3(CF_2)_6(CH_2)_3OH$ was prepared in a six-step sequence of reactions from R_FI by way of R_FCu, $R_FCH=CHI$ and $R_FCH=CHCOOH$ [13]. High yields were obtained in several steps, but the overall yield was modest. It should be mentioned, too, that the well-known zinc reduction could not be used for deiodination of $R_FCH_2CHICH_2OH$ (or of the acetate ester), as elimination to $R_FCH_2CH=CH_2$ occurred [14].

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CHART I

Reduction and Elimination Reactions of $R_FCH_2CHICH_2OH$

$R_FCH_2CHClCH_2OH$	Raney Ni, 130° H_2, 170 atm., NaOH	$R_F(CH_2)_3OH$ $R_F = CF_3(CF_2)_7$	[6]
	Raney Ni, 50°, EtOH H_2,10 atm, KOAc, 2h	$R_F(CH_2)_3OH$ $R_F = CF_3(CF_2)_6$	[7]
	Pd/C, 25°, EtOH, H_2, 4 atm., KOH, 60 h	$R_F CH_2CH(CH_3)OH$ $R_F = CF_3(CF_2)_6$	[8]
$R_FCH_2CHICH_2OH$	LiAlH$_4$, THF (or ether, reflux)	$R_F(CH_2)_3OH$ (52%) [loc cit] $R_F = CF_3(CF_2)_{2,3}$ [5]	
	NaOH, H$_2$O, 25°, 1 h (KOH, H$_2$O, 90°, 3 h)	$R_FCH_2CH{-}CH_2$ $\diagdown O \diagup$ $R_F = CF_3(CF_2)_{1,2}$	[5,9]
	KOH, CH$_3$OH, 67°, 8.5 h	$R_FCH=CHCH_2OH$ $R_F = CF_3(CF_2)_6$, $(CF_3)_2CF(CF_2)_4$	[12]
$R_FCH_2CH{-}CH_2$ $\diagdown O \diagup$	AlCl$_3$, ether LiAlH$_4$	$R_FCH_2CH(CH_3)OH$	[9]
$R_FCH_2CH{-}CH_2$ $\diagdown O \diagup$	Pd or Ni, 70°, H_2, 30 atm, AcOK, 4 h	$R_FCH_2CH(CH_3)OH$	[11]

Syntheses of $R_F(CH_2)_3OH$ *via* the Acetate Ester. For a very practical reason we were more interested in the synthesis of $R_F(CH_2)_3OH$ by way of the acetate ester than by way of the alcohol. It was easier to prepare the ester in high yield. Accordingly, starting with $R_FCH_2CHICH_2OAc$ from R_FI and $CH_2=CHCH_2OAc$, optimum conditions for the preparation of $R_F(CH_2)_3OH$ were studied; these new results will be contrasted with previous methods where appropriate.

Free radical addition of R_FI to allyl acetate, earlier catalyzed by azo-<u>bis</u>-isobutyronitrile (AIBN) [3], gave improved conversion (94%) and yield (99%), with benzoyl peroxide initiation. Best results were obtained when allyl acetate was added slowly to R_FI to minimize wastage of initiator and to control the reaction. By contrast, addition of R_FI to allyl alcohol required AIBN but repeated additions of initiator were necessary for high conversion, resulting in an impure product [9,15].
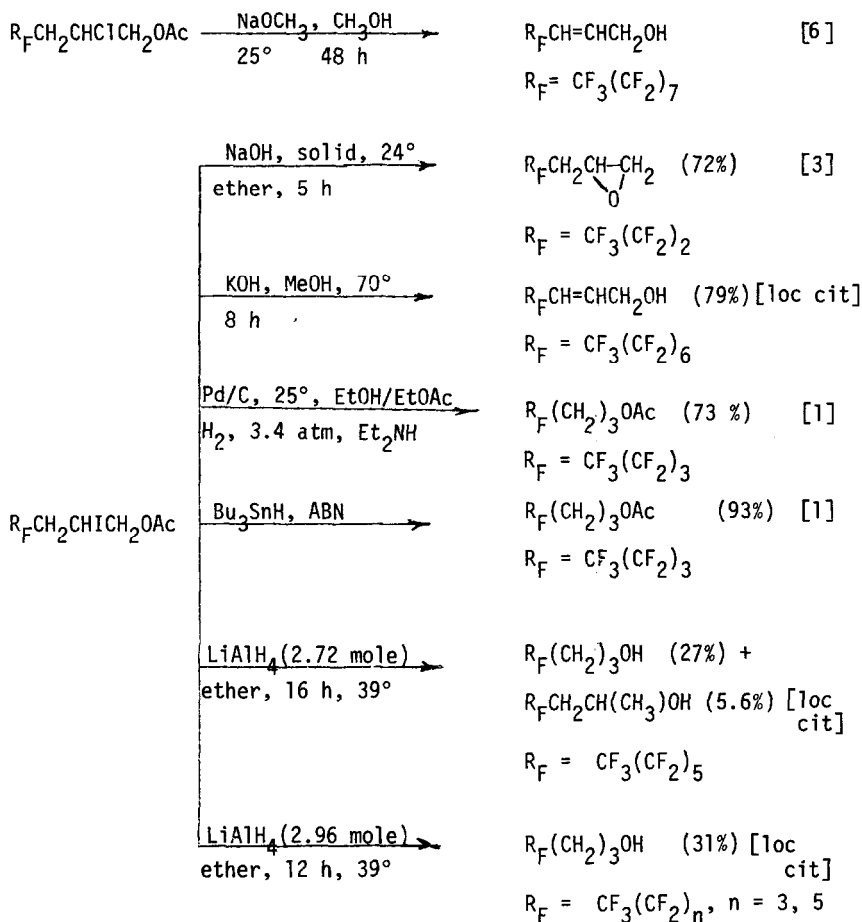
In our hands reduction of $R_FCH_2CHICH_2OH$ ($R_F = CF_3(CF_2)_m$, m =3 or 5) to $R_F(CH_2)_3OH$ by $LiAlH_4$ in anhydrous ether or tetrahydrofuran gave incomplete reaction, only modest yields (40-52%) and over all poor recovery of material. Part of the difficulty resided in the extraction of these alcohols from the aqueous slurry of aluminum salts; this same problem arose in subsequent methods involving extraction from polar solvents. Great pains were taken to exclude moisture from these reactions. Reduction of $R_FCH_2CHICH_2$-OAc seemed to be even less satisfactory, and in one instance, $R_F = CF_3$-$(CF_2)_5$, gave a mixture of $R_F(CH_2)_3OH$ (27%) and the secondary alcohol, $R_FCH_2CH(CH_3)OH$ (5.6%). The mixture of alcohols was separated by fractional distillation and identified by GC/MS, NMR spectrum and retention times by GC analysis. Our materials and prodedure were quite satisfactory for the reduction of n-heptyl acetate [16].

Catalytic deiodination of $CF_3(CF_2)_5CH_2CHICH_2OAc$ over palladium on carbon was quantitative in a few minutes at room temperature (hydrogen at 3.4 atm. press., diethylamine acid acceptor). Either ethanol and ethyl acetate or dimethoxyethane were suitable solvents. The NMR spectrum confirmed the structure of the product as $CF_3(CF_2)_5(CH_2)_3OAc$, and it gave a single peak in GC analysis [1]. However, work-up gave only 73% recovery, the same amount recovered from a blank run.

The best laboratory procedure from the standpoints of yield and ease of operation made use of tributyltin hydride. No solvent was used and the pure ester $CF_3(CF_2)_3(CH_2)_3OAc$ distilled from the reaction mixture in 93% conversion and yield. The tributyltin iodide was recovered for re-use. GC analysis and spectroscopic properties demonstrated purity and structure of the ester. Conversion was lower when an alternate method using polymethylsiloxane and tributyltin oxide was employed [17].

Dehydroiodination of $CF_3(CF_2)_6CH_2CHICH_2OAc$ to $CF_3(CF_2)_6CH=CHCH_2OH$ by KOH in anhydrous methanol was accomplished in 79% yield [12]. Reduction to $R_F(CH_2)_3OH$ has been done [6]. The various reactions described above are shown in Chart II, including pertinent prior work.

CHART II

Reduction and Elimination Reactions of $R_FCH_2CHICH_2OAc$

$R_FCH_2CHClCH_2OAc$ $\xrightarrow[\text{25° \quad 48 h}]{\text{NaOCH}_3, \text{ CH}_3\text{OH}}$ $R_FCH=CHCH_2OH$ [6]

$R_F= CF_3(CF_2)_7$

$R_FCH_2CHICH_2OAc$

$\xrightarrow[\text{ether, 5 h}]{\text{NaOH, solid, 24°}}$ $R_FCH_2CH\!\!-\!\!CH_2$ (72%) [3]
$\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad O$

$R_F = CF_3(CF_2)_2$

$\xrightarrow[\text{8 h}]{\text{KOH, MeOH, 70°}}$ $R_FCH=CHCH_2OH$ (79%) [loc cit]

$R_F = CF_3(CF_2)_6$

$\xrightarrow[\text{H}_2, \text{ 3.4 atm, Et}_2\text{NH}]{\text{Pd/C, 25°, EtOH/EtOAc}}$ $R_F(CH_2)_3OAc$ (73 %) [1]

$R_F = CF_3(CF_2)_3$

$\xrightarrow{\text{Bu}_3\text{SnH, ABN}}$ $R_F(CH_2)_3OAc$ (93%) [1]

$R_F = CF_3(CF_2)_3$

$\xrightarrow[\text{ether, 16 h, 39°}]{\text{LiAlH}_4 (2.72 \text{ mole})}$ $R_F(CH_2)_3OH$ (27%) +

$R_FCH_2CH(CH_3)OH$ (5.6%) [loc cit]

$R_F = CF_3(CF_2)_5$

$\xrightarrow[\text{ether, 12 h, 39°}]{\text{LiAlH}_4 (2.96 \text{ mole})}$ $R_F(CH_2)_3OH$ (31%) [loc cit]

$R_F = CF_3(CF_2)_n$, n = 3, 5

$CF_3(CF_2)_6CH=CICH_2OH$ (from R_FI and 2-propyn-1-ol) when treated with zinc and acid (compare Park, et al [9]), gave $CF_3(CF_2)_6CH=CHCH_2OH$ (53.7 %) and a very reactive allenic compound ($\nu C=C=C$ 2000 and 1960 cm^{-1}; strong, sharp bands) that polymerized during distillation. See below for contrasting behavior of higher homologs.

Higher Homologs. Free radical addition of R_FI to 3-butyn-1-ol occurred readily (85 % conversion, 97 % yield; 70°, AIBN). Reduction by zinc and acid gave $CF_3(CF_2)_3CH=CHCH_2CH_2OH$ (85 % yield, cis and trans isomers).

Brace and Mackenzie [18] had previously prepared $CF_3(CF_2)_3(CH_2)_4OH$ from R_FI and 3-buten-1-ol, followed by zinc reduction of the adduct. The homolog having n = 11 also was synthesized in three steps from R_FI and 10-undecenoic acid (or ester) [18]. The adducts were reduced by zinc and acid to $R_F(CH_2)_{10}COOR$ [R_F = $CF_3(CF_2)_6$ or $CF_3(CF_2)_3CF(CF_3)$—] and then by $LiAlH_4$ to $R_F(CH_2)_{11}OH$. In the present work R_FI was added to 10-undecen-1-ol to give $R_FCH_2CHI(CH_2)_9OH$ [R_F = $(CF_3)_2CF$ or $CF_3(CF_2)_6$, 96 or 98% yield, resp.] using AIBN initiator. Dehydrohalogenation by KOH in alcohol-water solution gave $R_FCH=CH(CH_2)_9OH$ (94 or 92% yield, resp.). The unsaturated alcohols were not further hydrogenated in this work.

An oxa-linked homolog, $CF_3(CF_2)_6CH_2CHICH_2OCH_2CH_2OH$ was similarly prepared (94% yield) and reduced to the saturated alcohol (85% yield) by hydrogen over palladium on carbon. Accordingly, the methods employed for the synthesis of R_F-terminated alcohols $R_F(CH_2)_nOH$, having n = 4 or higher, can be reasonably extended to any homolog of the series, with the anticipation of good success.

EXPERIMENTAL

Sources of materials and special equipment

1-Iodo-F-butane, 1-iodo-F-hexane and 1-iodo-F-octane were obtained from the telomerization of tetrafluoroethylene with 1-iodo-F-ethane and were distilled before use [3,4,18]. 1-Iodo-F-propane, 2-iodo-F-propane and 1-iodo-F-heptane were purchased from Pierce Chem. Co., the alkenols and 2-propyn-1-ol, bp 112°, $n^{25}D$ 1.4301, from Aldrich Chem. Co., and azo-bis-isobutyronitrile from Eastman Kodak Co. 3-Butyn-1-ol, from Farchan Chem. Co., was re-distilled, bp 78°/99mm, n^{25}_D 1.4390. Distillation columns employed were a 6-inch Vigreaux column (A), a 16-inch stainless steel (Nester/Faust) spinning band column (B), a similar 36-inch column (C), and a similar 24-inch platinum column (D). Gas chromatography was done using a Sargent-Welch thermal conductivity instrument fitted with a 6-ft by 1/4-inch column packed with 'FFAP' resin (10%) on Chromosorb WA or a 4.5 ft by 1/4-inch column packed with SE30 Silicone oil (10%) on Chromosorb WA. Infrared spectra were obtained using a Perkin Elmer grating spectrophotometer Model 337 and NMR spectra were obtained using a Varian HA 100 spectrometer.

Free Radical Addition of 1-Iodo-F-Alkanes

(a) 3-(F-Hexyl)-2-iodopropyl acetate (1)

1-Iodo-F-hexane (92.5 g, 0.196 mole, 94.5% pure) and benzoyl peroxide (0.9688 g, 4.00 mmole) were heated under nitrogen while stirring, and allyl acetate (2, 20.2 g, 0.200 mole) was added slowly by means of a dropping funnel fitted with a needle valve during 1 h, at 89-93° (bath temperature 86-93°, exothermic reaction). The colorless liquid was kept at 96° for 2 h and distilled to give 1(nc), bp 62°/0.05 mm, 100.8 g, n^{25}_D 1.3822, 93.6% of theory. NMR: $\delta 2.03$, 3 H, s, CH_3; $\delta 2.90$, 2 H, t x d, J(HF)=20 Hz, J(HH)= 5 Hz; $\delta 4.36$, 3.0 H, complex multiplet, CH_2O, CHI. Analysis: Found: C, 24.5; H, 1.39; F, 44.6; I, 23.1%. $C_{11}H_8F_{13}IO_2$ requires C, 24.19; H, 1.48: F, 45.2; I, 23.2%.

(b) 3-(F-Heptyl)-2-iodopropyl acetate (3)

In like manner 1-iodo-F-heptane (4, 50.0g, 0.100 mole), benzoyl peroxide (0.484 g, 2.00 mmole) and 2 (10.0g, 0.100 mole) gave 3 (nc), bp 103-105°/2.0 mm, n^{25}_D 1.3782, 55.4 g, 93.5% of theory; residue, 1.2 g; and trap liquid, 2.4 g.   Analysis: Found: C, 25.02; H, 1.46; F, 48.01; I, 23.96%. $C_{12}H_8F_{15}IO_2$ requires C, 24.18; H , 1.35; F, 47.81; I, 21.29%.

(c) 3-(F-Butyl)-2-iodopropyl acetate (5)

Similar process using 1-iodo-F-butane (6, 34.6 g, 0.100 mole), 2 (10.01 g, 0.100 mole) and azo-bis-isobutyronitrile (7, 0.328 g, 2.00 mmole), stirred at 70° for 18 h gave 5(nc), bp 52°/0.2 mm, 34.0 g, (76.1%), n^{25} 1.3955; trap liquid (4.73 g); and residue (2.36 g). Alternatively, 6 (76.0 g, 0.220 mole) 2 (20.00 g, 0.200 mole) and 7 (0.656 g, 4.00 mmole), in a sealed tube that had been evacuated and filled with nitrogen three times at -70°, were heated at 70° for 18 h while stirring by magnet bar. Distillation afforded 5, bp 75°/2.0 mm, 79.76 g, 89.0% conversion. NMR was identical to that of 1. IR: ν(C=O) 1748 cm^{-1}. Analysis: Found: C, 24.96; H, 2.02; F, 37.29; I, 28.02%. $C_9H_8F_9IO$ requires C, 24.73; H, 1.81, F, 38.34; I, 28.45%.

(d) 3-(F-Butyl)-2-iodopropan-1-ol (8)

6 (104 g, 0.300 mole), allyl alcohol (9, 1.42 g, 0.300 mole) and 7 (0.94515 g, 6.00 mmole) were charged to a pressure tube and processed as in (c) above. Distillation (Column A) gave 6 and 9 (45.7 g); and 8 (nc),

bp 58-57°/0.8 mm, 58.1 g, 47.7% conversion. GC analysis showed 97.9% of <u>8</u> and 0.58% of unknown substances. NMR: $\delta 2.98$, 2 H, t x d, J(HF) = 19 Hz and J(HH) = 6 Hz; $\delta 3.92$, 2 H, d, J(HH) = 5 Hz, CH_2O; $\delta 4.45$, 1 H, m, CHI.

(e) 3-(F-Heptyl)-2-iodo-2-propen-1-ol (<u>10</u>)

1-Iodo-F-heptane (<u>4</u>, 81.0 g, 0.163 mole), 2-propyn-1-ol (<u>11</u>, 9.2 g, 0.163 mole) and <u>7</u> (0.656 g, 4.00 mmole) were charged to a flat-bottomed pressure bottle, stirred by a magnet bar, and processed as in (d). After 1.5 h the mixture was homogeneous, and after 18.5 h it was distilled, to give: <u>4</u> and <u>11</u> (39.8 g); <u>10</u>(nc), bp 91-98°/ 2.0 mm, n_D^{25}1.3863, 45.0 g, 49% conversion, 85% yield; residue (3.4 g). GC analysis: two substances, 58.6 and 37.7 area%. IR:ν(C=C) 1640 cm^{-1}, bands at 990, 890, 835, 815, 740, 720, 650 and 530 cm^{-1}. NMR: $\delta 6.1$ to 7.2,m, CH=CI; $\delta 4.3$, 2 H, CH_2OH; $\delta 3.2$, 1 H, exchangeable, s, OH. Analysis: Found: C, 21.77; H, 0.86; F, 51.45; I, 22.54%. $C_{10}H_4F_{15}IO$ requires C, 21.75; H, 0.73; F, 51.63; I, 22.99%.

(f) 4-(F-Butyl)-3-iodo-3-butene-1-ol (<u>12</u>)

1-Iodo-F-butane (<u>6</u>, 69.2 g, 0.210 mole), 3-butyne-1-ol (<u>13</u>, 14.0 g, 0.200 mole) and <u>7</u> (0.656 g, 4.00 mmole), processed as in (d) at 70° for 26 h and distilled (Column B), gave <u>12</u> (nc), 83-84°/3.6 mm, n_D^{25} 1.4142, 71.0 g, 85% conversion and 97% yield. IR: ν(C=C)1630 cm^{-1}, bands at 1050, 980, 930, 880, 740, 695, 590 and 520 cm^{-1}. Analysis: Found: C, 23.12; H, 1.47; F, 40.90; I, 30.68%. $C_8H_6F_9IO$ requires C, 23.08; H, 1.45; F, 41.08; I, 30.49%.

(g) 4-(F-Heptyl)-3-iodo-3-butene-1-ol (<u>14</u>)

<u>4</u> (99.2 g, 0.200 mole), <u>13</u> (14.0 g, 0.200 mole) and <u>7</u> (0.654 g, 4.00 mmole), processed as in (d) at 70° for 15.5 h, and distilled, gave <u>4</u> and <u>13</u> (15.9 g) and <u>14</u> (solid, nc), 99.2 g, 88 % conversion. A 10-g aliquot of <u>14</u> was distilled, bp 74°/0.05 mm, 9.6 g. NMR (undistilled <u>14</u>): $\delta 2.31$, s, OH; $\delta 2.9$, 2 H, t, $\underline{CH_2}CH_2OH$; $\delta 3.8$, 2 H, t, $CH_2\underline{CH_2}OH$. $\delta 6.47$, 1 H, t, CH=CHI. Long range coupling of $C\underline{F_2}CH=CICH_2$ was seen as splitting of the $\delta 2.9$ resonance. GC analysis showed 1.5 % of an impurity, and 83.6 and 14.5 % of <u>cis</u> and <u>trans</u> isomers of <u>14</u>.

(h) 11-(F-Isopropyl)-10-iodoundecan-1-ol (<u>15</u>)

2-Iodo-F-propane (62.5 g, 0.210 mole), 10-undecen-1-ol (<u>16</u>, 34.2 g, 0.200 mole) and <u>7</u> (0.656 g, 4.00 mmole) kept as in (d) at 70° for 26 h, and

distilled, gave $\underline{15}$ (nc), bp 121/0.30 mm, n^{25}_D 1.4390, 85.0 g, 96.4% yield. Analysis: Found: C, 36.16; H, 4.75; F, 28.62; I, 27.28%. $C_{14}H_{22}F_7IO$ requires C, 36.06; H, 4.76; F, 28.53; I, 27.22%.

(i) 11-(F-Heptyl)-10-iodoundecan-1-ol (17)

Similarly, $\underline{4}$ (100 g, 0.200 mole), $\underline{16}$ (34.5 g, 0.202 mole) and $\underline{7}$ (0.990 g, 6.00 mmole) kept as in (d) at 70° for 17 h, gave $\underline{17}$ (nc) , 130.6 g, 98% conversion. A 20 g-aliquot was distilled, bp 129-132°/0.15 mm, n^{25}_D 1.4101, 17.0 g, and residue, 1.0 g. NMR: δ1.2-2.2, 16 H, m, $(CH_2)_8$; δ2.23, 1 H, s, OH; δ3.71, 2 H, t, CH_2OH; δ4.43, 1 H, 5 lines, $CH_2\underline{C}HICH_2$. Analysis: Found: C, 32.90; H, 3.49; F, 42.50; I, 22.68%. $C_{18}H_{22}F_{25}IO$ requires C, 32.45; H, 3.33; F, 42.78; I, 19.05%.

(j) 6-(F-Heptyl)-5-iodo-3-oxa-hexan-1-ol (18)

$\underline{4}$ (165 g, 0.200 mole), 3-oxa-5-hexene-1-ol (2-allyloxyethanol, 34.4 g, 0.334 mole) and $\underline{7}$ (2.28 g, 13.4 mmole) kept as in (d) at 70° for 22 h, and distilled gave $\underline{18}$ (nc), bp 100°/0.18 mm, n^{25}_D 1.3914, 90% conversion, (95% yield). Benzoyl peroxide initiation gave only 40% conversion.

Lithium Aluminum Hydride Reductions [6, 16, 19]

(a) 3-(F-Butyl)propan-1-ol(19) from 3-(F-Butyl)-2-iodopropan-1-ol (8)

A 3-necked, 500 ml flask, placed inside a nitrogen-filled bag, was charged with anhydrous diethyl ether (200 ml), lithium aluminum hydride (LAH 17.00 g, 0.448 mole) and then set up under nitrogen purge. An addition funnel (also inside the bag) was charged with $\underline{8}$ (45.50 g, 0.1735 mole) and dry ether (60 ml). The mixture was stirred while the solution of $\underline{8}$ was added (0.5 h, reflux, hydrogen evolution). After 3 h at reflux, the mixture was decomposed by cautious addition of sulfuric acid (45 ml in 200 ml of water), extracted twice with ether (50 ml) and the organic layer washed with $NaHCO_3$ (15 ml, saturated) and dried $(MgSO_4)$. Distillation in Column A gave fractions: I, bp (33°)/15 mm, 3.96 g; II, bp 64-68°/15 mm, 12.87 g; III, bp 83-92°/15 mm, 4.72 g, a residue of 1.76 g; and trap liquid (6.45 g). GC analysis, ("FFAP" temperature programmed at 24°/min. from 50 to 200°) gave areas: I, 90.4% of $\underline{19}$, and 5.27% of $\underline{8}$; II, 84.3% of $\underline{19}$ and 13.2% of $\underline{8}$; III, 18.5% of $\underline{19}$ and 80.7% of $\underline{8}$. Thus, recovery of $\underline{8}$ was 12.0% and conversion to $\underline{19}$ was 46.8%.

The reaction was repeated using anhydrous tetrahydrofuran (120 ml) that had been distilled from LAH. 8 (40.02 g, 0.0991 mole) in 40 ml of tetrahydrofuran was added during 0.5 h at 33-68° to LAH (37.95 g, 0.2005 mole) and stirring continued for 5.5 h at 68°. Work-up as above gave fractions: I, bp 33-63°/25-16 mm, 6.66g; and II, bp 69-70°/15 mm, 7.56g; and liquid hold-up, 1.44 g. GC analysis ("FFAP" and "SE 30") of I and II gave 99.4% purity; 52% total conversion and yield.

(b) 19 from 3-(F-Butyl)-2-iodopropyl acetate (5)

5 (65.01 g, 0.1457 mole) in dry ether (75 ml) was added during 1 h to LAH (15.70 g, 0.4317 mole) in 220 ml of ether at 31-35°, and heated to reflux for 12 h. Work-up as in (a) gave fractions: I, bp 65-66°/15 mm, 2.80 g; II, bp 67-68°/15 mm, 10.39 g; and residue, 1.65 g. GC analysis ("FFAP") gave: I, 3.16% and 4.99% of unknowns; 89.5% of 19; II, 1.13% and 2.27% of unknowns and 96.26% of 19. Total conversion to 19 (nc) was 30.8%. NMR (19): δ1.87, 4 H, complex, $R_FCH_2CH_2$; δ3.70, 2 H, t, J(H-H) = 5 Hz, CH_2O; δ4.80, 1 H, s, OH. Analysis: Found: C, 30.3; H, 2.52; F, 61.8%. $C_7F_9H_7O$ requires C, 30.2; H, 2.54; F, 61.8%.

(c) 3-(F-Hexyl)-propan-1-ol (20) and 3-(F-hexyl)propan-2-ol (21) from 3-(F-hexyl)-2-iodo-propyl acetate (1)

1 (85.12 g, 0.1588 mole) in 65 ml of ether was added to LAH (16.10 g, 0.4242 mole) in 280 ml of ether during a half h at 35°, and stirred for 16 h at 39°. The reaction mixture was worked-up as in (a). Distillation gave an impure mixture, bp 77-88°/14 mm, 24.1 g. Fractionation of this material (column B) gave fractions listed in Table I:

Table I
Distillation and GC Analysis of Isomeric Alcohols 20 and 21

Retention Time (min) [a]				3.6	4.7	5.5	6.2	7.5
Identity				21	unk.	20	unk.	unk.
Fraction	bp/14 mm	Wt, g	n_D^{25}	Relative Area, Per Cent				
I	60-77°	1.11		78.6	4.35	13.9	3.13	--
II	75-78°	1.16		77.1	5.48	15.3	0.68	1.37
III	81-83°	2.00		56.3	8.5	35.8	--	1.27
IV	84-87.5°	9.57		4.1	2.7	93.1	--	--
V	87°	6.49	1.3250	--	--	100	--	--

[a] 'SE 30', temperature-programmed, 80-300°, 10°/min, 45 ml/min helium

The conversion to 20 (nc) was 28.0% of theory and to 21 (nc) was 5.56%. NMR (20): δ1.65-2.55, 4 H, complex, $R_FCH_2CH_2$; δ2.40, 1 H, s, OH; δ3.75, 2 H, t, J = 5 Hz, CH_2O. Analysis: Found (20): C, 28.97; H, 2.10; F, 65.19%. $C_9F_{13}H_7O$ requires C, 28.58; H, 1.87; F, 65.32%. GC/MS on the 5.5 min peak (20) gave a base peak, m/e = 31 ($CH_2=\overset{+}{O}H$), and lesser amounts of m/e = 29 ($CH\overset{+}{O}$) and m/e = 28 (C≡O). The 3.6 min peak (21) gave a base peak of m/e = 43 ($CH_2C=O$), and a smaller peak for m/e = 29 ($CH\overset{+}{O}$). The molecular ion was not observed for either alcohol, but a large number of fragmentation peaks, typical of the fluorinated chain. Fraction I (78.6% of 21) gave an NMR spectrum: δ1.4, 0.73 H, d, J = 7 Hz, CH_3CH; δ2.24, 1.3 H, t, J = 20 Hz, CF_2CH_2 of 21 and $CF_2CH_2CH_2$ of 20; δ3.75, 1.5 H, s and m, OH of 21 and CH_2OH of 20; δ4.4, 0.73 H, 6-lines, J = 7 Hz, CH_3CH of 21.

(d) n-Heptyl acetate

The method and materials used above were checked for the reduction of n-heptyl acetate. To LAH (29.00 g, 0.7642 mole) in ether (300 ml) was added n-heptyl acetate (62.0 g, 0.3918 mole) in ether (100 ml) during 1 h at 32°. After 24 h at 37° work-up gave 1-heptanol, bp 78-89°/16 mm, 38.2 g, 77% conversion and recovery, 97.1% pure by GC analysis.

Tributyltin Hydride Reduction of 3-(F-Butyl)-2-iodopropyl Acetate (5)

Tributyltin hydride was prepared by LAH reduction of tributyltin chloride, and distilled, bp 79°/0.4 mm. 5(26.87 g, 0.0600 mole) and 7 (0.0328 g, 0.200 mmole), kept under nitrogen, was stirred by magnet bar at 50-65°, as tributyltin hydride (17.87 g, 0.0616 mole) was added drop-wise during 3.75 h. Distillation gave 3-(F-butyl)propyl   acetate (22), (nc), bp74-78°/14 mm, 18.0 g (93%); a fraction, bp 52-72°/0.10 mm, 1.15 g; tributyltin   iodide, bp 98°/0.10 mm, 24.87 g; residue (1.00 g); and trap liquid (0.22 g). IR: νC=O, 1740 cm^{-1} and fingerprint bands at 1030, 995, 930, 880, 835, 748, 735, 718 and 605 cm^{-1}. NMR: δ1.8-2.8, 4 H, m, R_F-CH_2CH_2; δ2.05, 3 H, s, O_2CCH_3; δ4.18, 2 H, t, J = 7 Hz, CH_2OAc. Analysis: Found: C, 33.43; H, 2.77; F, 53.73%. $C_9H_9F_9O$ requires C, 33.14; H, 2.83; F, 53.41%.

Zinc Reduction of Adducts

(a) 3-(F-Heptyl)-2-propen-1-ol (23) from 3-(F-heptyl)2-iodo-2-propen-1-ol (10)

10 (93.6 g, 0.170 mole), ethanol (500 ml) and zinc (30 mesh, 30.0 g, 0.46 g-atom) were heated to 82° and stirred rapidly while HCl was bubbled

in. After 1 h IR showed: νOH 3500-3200; νCH 3050, 2980, 2930, and 2860; νC=C=C, 2 sharp bands, 2000 and 1960; νC=C 1680 and 1660 cm^{-1}. After 2 h at 76-78° an additional 10 g (0.153 g-atom) of zinc was added and after 4 h ethanol was distilled from the mixture. The yellow liquid was poured into water (300 ml), extracted with ether (150 ml, 50 ml) and with dichloromethane (twice, 50 ml), rinsed with aqueous sodium bisulfite and dried (MgSO$_4$). Distillation (column D) from an oil bath gave 23 (nc), bp 97-98°/14 mm, n$^{25}_D$ 1.3310, 38.9 g, 53.7% of theory; darkening of the pot liquid and polymerization of unstable material occurred with the bath temperature at 126-131°. The residue (21.5 g) was a dark brown solid. IR (23): νC=C 1680, 1660; νCH 1450, 1410, 1360, 1350; and bands at 1100, 1085, 1070, 980, 955, 885, 830, 805, 775, 740, 730, 720, 700, 665, 640, 565 and 530 cm^{-1}. The allenic bands were absent. GC: two isomers, 46.3% and 52.7%. NMR: δ2.45, 1 H, s, OH; δ4.35, 2 H, m, CH$_2$O: δ5.6-6.8, 2 H, m, CH=CH. Analysis: Found: C, 28.24; H, 1.28; F, 66.25%. C$_{10}$H$_5$F$_{15}$O requires C, 28.18; H, 1.18; F, 66.88%.

(b) 4-(F-Butyl)-3-butene-1-ol (24) from 4-(F-butyl)-3-iodo-3-butene-1-ol (12)

Zinc (10 g, 0.15 g-atom, 30 mesh) and 12 (64.0 g, 0.153 mole) were added to ethanol (300 ml) while stirring at 72°; portions of zinc (10 g, 60-200 mesh) were added during 1 h at 80°, and after 4 h, ethanol (200 ml) was removed by steam distillation. Work-up as above gave 24 (nc), bp 93°/30 mm, n$^{25}_D$ 1.3453, 40.7 g, 91% of theory in three fractions. GC: 99.0, 99.4 and 99.4% purity. IR: νC=C 1665 cm^{-1}. NMR: δ2.2, 1 H, s, OH; δ2.55, 1 H, m, =CHCH ; δ3.7, 2 H, t, CH$_2$OH; δ5.1-6.8, 2 H, m, CH=CH. Analysis: Found: C, 33.22; H, 2.56; F, 59.09%. C$_8$H$_9$F$_9$O requires C, 33.11; H, 2.43; F, 58.94%.

(c) 4-(F-Heptyl)-3-butene-1-ol (25) from 4-(F-heptyl)-3-iodo-3-butene-1-ol (14)

Zinc (26.0 g, 0.40 g-atom) in ethanol (400 ml) and 14 (89.2 g, 0.157 mole), as above, gave 25 (nc), bp 111°/15 mm, n$^{25}_D$ 1.3393, 58.5 g, 84.6% of theory, in three fractions. GC: 98.9%. Analysis: Found: C, 30.38; H, 1.62; F, 64.50%. C$_{11}$H$_7$F$_{15}$O requires C, 30.01; H, 1.60; F, 64.75.

Dehydroiodination of Adducts to $R_FCH=CH(CH_2)_nOH$

(a) 3-(F-Heptyl)-2-propen-1-ol (23) from 3-(F-heptyl)-2-iodo-propyl acetate (3)

3 (50.15 g, 0.084 mole) was added slowly during 5 h at 45° to KOH (13.3 g, 0.238 mole) in anhydrous methanol (100 ml), kept at 70° under nitrogen for 8 h. Methanol was distilled off to 80° (inside temperature). The slurry was poured into water (150 ml), extracted with chloroform (twice, 40 ml), aqueous sodium bisulfite, and dried (MgSO$_4$). Distillation (column B) gave fractions: I, bp 94-97°/11 mm, 4.85 g; II, bp 104-105°/10 mm, n^{25}_D 1.3330, 43.45 g; III, bp 72°/0.30 mm, 1.05 g; residue, 4.0 g. Conversion to 23 (nc) was 79%. GC: cis and trans isomers of 23. NMR: same as 23 above, but impurities present.

(b) 11-(F-Isopropyl)-10-undecen-1-ol (26) from 11-(F-isopropyl)-10-iodoundecan-1-ol (15)

To a solution of KOH (11.2 g, 0.200 mole) in water (50 ml) and ethanol (200 ml) was added 15 (79.4 g, 0.170 mole) at 35°, stirring continued for 15.5 h, and the mixture poured into 100 ml of water. The organic product was extracted with ether (three times, 50 ml), washed with aqueous sodium bisulfite and dried (MgSO$_4$). Distillation (column B) gave 26 (nc), bp 113-116°/2.4 mm, n^{25}_D 1.3964, 53.3 g, 94% yield. IR: νC=C 1670 cm^{-1}. Analysis: Found: C, 50.99; H, 6.37; F, 39.11%. $C_{14}H_{21}F_7O$ requires C, 49.70; H, 6.25; F, 39.31%.

(c) 11-(F-Heptyl)-10-undecen-1-ol (27) from 11-(F-heptyl)-10-iodoundecan-1-ol (17)

17 (110 g, 0.165 mole) and KOH (11.2 g, 0.200 mole) gave, when processed as above, 27 (nc), bp 114°/0.21 mm, n^{25}_D 1.3764, 81.4 g, 91.5%. IR: νC=C 1670 cm^{-1}. NMR: δ1.32, 14 H, s, (CH$_2$)$_7$; δ1.54, 1 H, s, OH; δ2.2, 2 H, m, =CHCH$_2$; δ3.63, 2 H, t, CH$_2$OH. Analysis: Found: C, 40.10; H, 3.95; F, 53.08%. $C_{18}H_{21}F_{15}O$ requires C, 40.15; H, 3.93; F, 52.94%.

(d) 6-(F-Heptyl)-3-oxa-5-hexen-1-ol (28) from 6-(F-heptyl)-5-iodo-3-oxahexan-1-ol (18)

18 (90.0 g, 0.150 mole) was added to KOH (11.2 g, 0.200 mole), and as above, gave 28 (nc), bp 98-100°/1.5 mm, n^{25}_D 1.3490, 65.2 g, 93.0%, three fractions. IR: νC≈C 1680 cm^{-1}. NMR: δ2.82, 1 H, s, OH; δ3.61,

Catalytic Hydrogenation of Unsaturated Alcohols

(a) 6-(F-Heptyl)-3-oxa-hexan-1-ol (29) from 28

6-(F-Heptyl)-3-oxa-5-hexen-1-ol (28, 47.0 g, 0.100 mole), 3.0 g of
10% palladium on carbon and ethanol (90%, 100 ml) were shaken at 27-30°
under 50 psi (gauge) of hydrogen pressure, during 22 h in a Parr shaker ap-
paratus. The pressure drop was quantitative. The slurry was filtered,
rinsed with ethanol (95%) and benzene and distilled (column C). 29 (nc),
bp 101°/1.5 mm, n^{25}_D 1.3468, 32.1 g, 72% recovery. Redistilled, bp 91°/1.1
mm, n^{25}_D 1.3425. GC: 99.2% pure. NMR: $\delta 1.6-2.9$, 4 H, m, $CF_2CH_2CH_2$;
$\delta 3.55$, 6 H, m, $CH_2OCH_2CH_2OH$; $\delta 2.95$, 1 H, s, OH, exchangeable proton. Anal-
ysis: Found: C, 30.49; H, 2.27; F, 60.24%. $C_{12}H_{11}F_{15}O_2$ requires C,
30.52; H, 2.35; F, 60.35%.

Catalytic Deiodination of Adducts

(a) 3-(F-Hexyl)propyl acetate (30) from 3-(F-hexyl)-2-iodo-propyl acetate (1)

Adduct 1 (53.1 g, 0.0878 mole), diethylamine (8.04 g, 0.110 mole),
palladium on carbon (5%, 5.00 g), ethanol (anhydrous, 50 ml) and ethyl ace-
tate (100 ml) were charged to a Parr hydrogenation bottle. In fifteen min-
utes quantitative up-take of hydrogen had occurred (3.40 atm of hydrogen).
GC: one peak only for 30. (Using dimethoxyethane as solvent also gave
quantitative reduction). The product mixture was filtered under nitrogen,
stripped on a rotary evaporator to 40°/80 mm, washed with water (100 ml),
extracted with ether (twice, 30 ml), benzene (25 ml) and dried ($MgSO_4$).
Distillation (column B) gave 30 (nc), bp 93°/11 mm, n^{25}_D 1.3320, 26.6 g,
(72.1%). Potassium carbonate as acid acceptor gave complete reduction but
afforded 30 (22.3 g) and 3-(F-hexyl)propan-1-ol (20, 1.04 g). Sodium ace-
tate in acetic acid [20] was unsuccessful; 1 was recovered unchanged (72.2%
of theory). Analysis: Found: C, 31.65; H, 2.07; F, 60.0%. $C_{11}F_{13}H_9O$
requires C, 31.44; H, 2.16; F, 58.78%.

(b) 6-(F-Heptyl)-3-oxa hexan-1-ol (29) from adduct 18

18 (59.8 g, 0.100 mole), KOH (8.4 g, 0.15 mole) and palladium on car-
bon (5%, 4.00 g) in methanol (150 ml) were shaken at 40 psi (gauge) of
hydrogen pressure for 15 h. The product was worked-up as above, and gave
(column B) 29 (nc), bp 94°/1.1 mm, 40.42 g, n^{25}_D 1.3443-1.4330, 85%.

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