Improved Microwave-Assisted Ring Opening of 1,1,1-Trifluoro-2,3-epoxypropane: Synthesis of New 3-Alkoxy-1,1,1-trifluoropropan-2-ols

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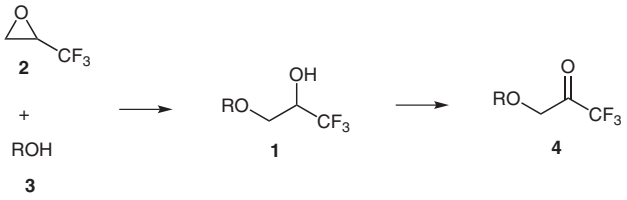
Abstract: A highly efficient and environmentally friendly method for the synthesis of 3-alkoxy-1,1,1-trifluoropropan-2-ols is presented. The approach involves ring-opening reaction of 1,1,1-trifluoro-2,3-epoxypropane with structurally different long-chain alcohols under microwave irradiation at room temperature in the absence of solvent. These chemicals are precursors of the corresponding trifluoromethyl ketones, potent inhibitors of human and murine liver microsomes and porcine liver esterase.

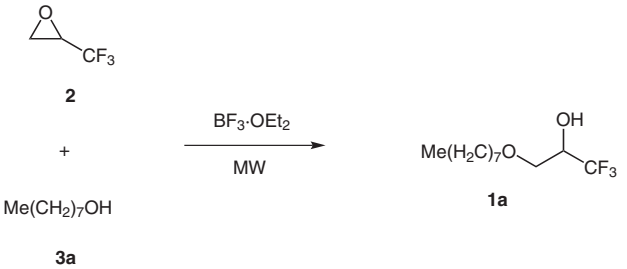
Key words: 1,1,1-trifluoro-2,3-epoxypropane, ring opening, trifluoromethyl carbinols, trifluoromethyl ketones, microwave catalysis

Trifluoromethyl carbinols are important intermediates in the synthesis of polyfunctional bioactive molecules[1] and have been used as synthons in the construction of anti-ferroelectric liquid crystalline molecules.[2] They are also precursors of trifluoromethyl ketones (TFMK), an important class of compounds, which have resulted potent inhibitors of hydrolytic enzymes including carboxylesterases,[3] proteases,[4] human phospholipases,[5] fatty acid amide hydrolase,[6] etc. Hammock and co-workers found that the introduction of a heteroatom (S, O) in the β-position to the carbonyl group increased the inhibition potency of these compounds, producing potent inhibitors of human liver microsomes, murine liver microsomes, and porcine liver esterase.[7] Very few papers have described the synthesis of ether-substituted TFMK **4**.[5,7] In this paper, we present a straightforward, environmentally friendly approach for the synthesis of 3-alkoxy-1,1,1-trifluoropropan-2-ols **1**, many of them previously unknown in the literature, precursors of **4**. The approach involves microwave-induced ring cleavage of 1,1,1-trifluoro-2,3-epoxypropane (**2**) with long-chain alcohols **3** in the presence of a Lewis acid as catalyst (Scheme 1). Since the pioneering work by McBee et al.[8] in 1956 on the ring cleavage of 1,1,1-trifluoro-2,3-epoxypropane with ethanol, there have been only a further few reports and these used simple alcohols (MeOH, EtOH, BnOH) in the presence of sulfuric acid.[9–11] Moreover, when longer chain alcohols were used, such as hexan-1-ol, the expected ring-opening product resulted in low yield (47%).[9] Therefore, we envisioned that microwave irradiation could improve the performance of the ring-opening reaction to prepare also long-chain trifluoromethyl carbinols. The results of this investigation are reported herein.



Scheme 1 Ring opening of 1,1,1-trifluoro-2,3-epoxypropane (**2**) with alcohols **3**

Initial trials for the reaction of (*Z*)-tetradec-9-en-1-ol (**3e**) with fluorinated epoxide **2** under Lewis acid catalysts (Table 1), such as copper(I) cyanide and aluminum(III) chloride, in tetrahydrofuran at 45 °C for 48 hours failed to produce the expected trifluoromethyl carbinol **1e** (entries 1 and 2). When the reaction was conducted at room temperature for 24 hours using boron trifluoride–diethyl ether complex as the catalyst in dichloromethane, the desired fluorinated alcohol **1e** was obtained in 43% yield along with 51% of unreacted alcohol **3e** (entry 3). Increasing the temperature to 45 °C yielded alcohol **1e** in a moderate 68% yield (entry 4). Similar results were obtained using a shorter and, in principle, more reactive alcohol such as octan-1-ol (**3a**) (entries 5 and 6). To improve these results, microwave irradiation appeared a promising alternative (Scheme 2).



Scheme 2 Microwave-assisted alcoholysis reaction of 1,1,1-trifluoro-2,3-epoxypropane (**2**) with octan-1-ol (**3a**)

Thus, when the reaction of epoxide **2** and octan-1-ol (**3a**) in presence of 1 mol% of boron trifluoride–diethyl ether complex and in the absence of solvent was implemented

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Table 1 Optimization Experiments for the Alcoholysis Reaction of 1,1,1-Trifluoro-2,3-epoxypropane (**2**)

Entry	Alcohol[a]	Ratio **2**/**3**	Catalyst	Temp (power, time)[b]	Solvent	Yield[c] (%)
1	**3e**	1:0.8	CuCN	45 °C (–, 48 h)	THF	–
2	**3e**	1:0.8	$AlCl_3$	45 °C (–, 48 h)	THF	–
3	**3e**	1:0.8	$BF_3{\cdot}OEt_2$	r.t. (–, 24 h)	CH_2Cl_2	43 (**1e**), 51 (**3e**)
4	**3e**	1:0.8	$BF_3{\cdot}OEt_2$	45 °C (–, 24 h)	CH_2Cl_2	68 (**1e**)
5	**3a**	1:0.8	$BF_3{\cdot}OEt_2$	r.t. (–, 24 h)	CH_2Cl_2	41 (**1a**), 55 (**3a**)
6	**3a**	1:0.8	$BF_3{\cdot}OEt_2$	45 °C (–, 24 h)	CH_2Cl_2	70 (**1a**)
7	**3a**	1:0.8	$BF_3{\cdot}OEt_2$	45 °C (100 W, 0.25 h)	–	53 (**1a**)
8	**3a**	1:0.8	$BF_3{\cdot}OEt_2$	60 °C (100 W, 0.25 h)	–	79 (**1a**)
9	**3a**	1:1.25	$BF_3{\cdot}OEt_2$	60 °C (100 W, 0.25 h)	–	96 (**1a**)

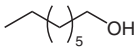
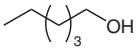
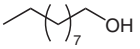
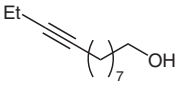
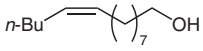
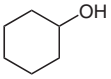
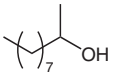
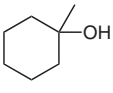
[a] For alcohols see Table 2.
[b] When applicable, power indicates initial microwave power, which is modulated to control the temperature.
[c] Isolated yields after column chromatography purification on silica gel.

in a microwave oven at 45 °C for 15 minutes, the expected carbinol **1a** was obtained in 53% isolated yield with no unreacted substrate being detected (entry 7). Increasing the reaction temperature to 60 °C improved the performance of the reaction (79% yield of **1a**, entry 8). However, the ratio of reagents used (**2**/**3a**, 1:0.8) meant that the concomitant formation of epoxide oligomers was also observed, as already found in a previous ring-opening methodology of nonfluorinated epoxides.[12] Increasing the ratio **2**/**3a** to 1:1.25 under the same conditions was sufficient to obtain compound **1a** in an excellent 96% yield, with no epoxide oligomers detected (entry 9). In the absence of the catalyst, the starting alcohol was recovered unchanged (entry not shown).

The optimized methodology was applied to structurally diverse alcohols and the results are summarized in Table 2. Moderate- or long-chain length saturated and unsaturated primary alcohols **3a**–**f**, secondary **3g**,**h**, and even tertiary alcohols **3i** provided good to excellent yields of the corresponding fluorinated alcohols **1a**–**i** (entries 1–9). In the case of **3i** we could not avoid, however, the undesired elimination reaction. The chain length of the alcohols had no effect on the yield of the process. Furthermore, no isomerization product in the reaction of **3e** (*Z*-isomer) was detected. Benzyl alcohol (**3j**) also gave the expected ring-opening product **1j** in excellent yield (91%, entry 10), significantly higher than that obtained under conventional conditions ($BF_3{\cdot}OEt_2$, BnOH, 45 °C, 65% yield).[11b] As model examples of being precursors of TFMK **4**, compounds **1a** and **1e** were converted into ketones **4a** and **4e** by Dess–Martin oxidation[13] in 78–81% yield.

In summary, the methodology described herein remarkably improves the performance of the ring-opening reaction of 1,1,1-trifluoro-2,3-epoxypropane (**2**) with alcohols **3** and expands the scope of previous epoxide opening reactions. The reaction is very fast (15 min), provides high-to-excellent yields of the corresponding fluorinated

Table 2 Microwave-Enhanced Reaction of 1,1,1-Trifluoro-2,3-epoxypropane (**2**) with Different Alcohols

Entry	Alcohol	Product	Yield[a] (%)
1	 **3a**	**1a**[14]	96
2	 **3b**	**1b**[7]	89
3	 **3c**	**1c**[14]	96
4	 **3d**	**1d**	81
5	 **3e**	**1e**	77
6	 **3f**	**1f**	67
7	 **3g**	**1g**	83
8	 **3h**	**1h**	86
9	 **3i**	**1i**	69
10	BnOH **3j**	**1j**[11b]	91

[a] Isolated yields after column chromatography purification on silica gel.

carbinols **1** under mild conditions and is environmentally friendly (no solvent is required). The fluorinated alcohols **1** prepared can be easily oxidized to the corresponding trifluoromethyl ketones **4** and therefore the outlined methodology represents also a formal synthesis of these potent enzyme inhibitors.

Chemicals were purchased from Sigma-Aldrich Química. Microwave reactions were carried out in a Discover apparatus (CEM, USA). IR spectra were recorded on a Bomem MB-120. ^{1}H NMR spectra were recorded on a Varian Unity spectrometer operating at 300 or 500 MHz, ^{13}C NMR at 75 or 100 MHz and ^{19}F NMR at 376 MHz; TMS (^{1}H,^{13}C) and $CFCl_3$ (^{19}F) as internal standard. Mass spectra were obtained on a Fisons MD 800 instrument. HRMS was obtained on a UPLC Acquity (Waters, USA) instrument coupled to a mass spectrometer LCT Premier XE.

1,1,1-Trifluoro-3-(octyloxy)propan-2-ol (1a); Typical Procedure

Octan-1-ol (**3a**, 200 mg, 1.53 mmol), 1,1,1-trifluoro-2,3-epoxypropane (**2**, 107 mg, 0.96 mmol), and freshly distilled $BF_3{\cdot}OEt_2$ (2 μL, 16 μmol) were added to a microwave tube. The mixture was heated at 60 °C in a microwave oven (100 W) for 15 min and then cooled. The crude mixture was partitioned between Et_2O (10 mL) and H_2O (10 mL). The organic soln was separated, washed with 1 M $NaHCO_3$ and H_2O, dried ($MgSO_4$), filtered, and concentrated. The obtained pale yellow oil was purified by column chromatography (silica gel, hexane–Et_2O, 9:1) to afford **1a** (223 mg, 96%).

IR (film): 3420, 2929, 2858, 1467, 1382, 1276, 1180, 1145, 1122, 699 cm^{-1}.

^{1}H NMR (500 MHz, $CDCl_3$): δ = 4.14–4.08 (m, 1 H), 3.67 (dd, *J* = 10.0, 3.5 Hz, 1 H), 3.60 (dd, *J* = 10.5, 6.0 Hz, 1 H), 3.51 (t, *J* = 6.5 Hz, 2 H), 1.59 (m, 2 H), 1.34–1.27 (m, 10 H), 0.88 (t, *J* = 6.5 Hz, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 124.2 (q, *J* = 280 Hz, CF_3), 72.1 (CH_2), 69.3 (q, *J* = 31 Hz, *C*HCF$_3$), 67.9 (CH_2), 31.8 (CH_2), 29.4 (CH_2), 29.3 (CH_2), 29.2 (CH_2), 25.9 (CH_2), 22.6 (CH_2), 14.1 (CH_3).

^{19}F NMR (376 MHz, $CDCl_3$): δ = –78.30 (d, *J* = 6.4 Hz, CF_3).

MS (EI): *m*/*z* (%) = 242 (M^+, 1), 143 (85), 111 (85), 84 (64), 71 (100), 57 (97), 43 (84).

HRMS: *m*/*z* [M – H]$^+$ calcd for $C_{11}H_{20}F_3O_2$: 241.1415; found: 241.1408.

3-(Decyloxy)-1,1,1-trifluoropropan-2-ol (1c)

IR (film): 3420, 2930, 2858, 1275, 1146, 698 cm^{-1}.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 4.11–4.05 (m, 1 H), 3.70–3.51 (m, 2 H), 3.47 (t, *J* = 6.0 Hz, 2 H), 3.03 (br, 1 H), 1.54 (m, 2 H), 1.27 (m, 14 H), 0.88 (t, *J* = 6.0 Hz, 3 H).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 124.2 (q, *J* = 280 Hz, CF_3), 69.4 (q, *J* = 31 Hz, *C*HCF$_3$), 65.4 (CH_2), 36.3 (CH_2), 31.8 (CH_2), 29.6 (CH_2), 29.5 (CH_2), 29.2 (CH_2), 25.4 (CH_2), 25.3 (CH_2), 22.6 (CH_2), 19.4 (CH_2), 19.3 (CH_2), 14.1 (CH_3).

^{19}F NMR (376 MHz, $CDCl_3$): δ = –78.18 (d, *J* = 6.9 Hz, CF_3).

MS (EI): *m*/*z* (%) = 269 ([M – 1]$^+$, 2), 255 (14), 157 (100), 141 (34), 69 (40), 56 (70), 42 (71).

HRMS: *m*/*z* [M + H]$^+$ calcd for $C_{13}H_{26}F_3O_2$: 271.1885; found: 271.1891.

3-(Dodec-9-ynyloxy)-1,1,1-trifluoropropan-2-ol (1d)

IR (film): 3443, 2934, 2858, 2246, 1275, 1145, 912, 735 cm^{-1}.

^{1}H NMR (500 MHz, $CDCl_3$): δ = 4.10 (m, 1 H), 3.67–3.57 (m, 2 H), 3.49 (t, *J* = 6.5 Hz, 2 H), 3.21 (br s, 1 H), 2.12 (m, 4 H), 1.58 (m, 2 H), 1.45 (m, 2 H), 1.38–1.29 (m, 8 H), 1.09 (t, *J* = 7.5 Hz, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 124.1 (q, *J* = 280 Hz, CF_3), 81.6 (C), 79.5 (C), 72.0 (CH_2), 69.3 (q, *J* = 31 Hz, *C*HCF$_3$), 68.0 (CH_2), 29.3 (CH_2), 29.2 (CH_2), 29.1 (CH_2), 29.2 (CH_2), 28.7 (CH_2), 18.6 (CH_2), 14.3 (CH_3), 12.4 (CH_2).

^{19}F NMR (376 MHz, $CDCl_3$): δ = –78.28 (d, *J* = 7.9 Hz, CF_3).

MS (EI): *m*/*z* (%) = 294 (M^+, 1), 265 (4), 223 (9), 169 (25), 93 (100), 79 (99), 67 (99), 55 (66).

HRMS: *m*/*z* [M + H]$^+$ calcd for $C_{15}H_{26}F_3O_2$: 295.1885; found: 295.1874.

1,1,1-Trifluoro-3-[(*Z*)-tetradec-9-enyloxy]propan-2-ol (1e)

IR (film): 3447, 2928, 2856, 1275, 1177, 1146 cm^{-1}.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 5.35 (m, 2 H), 4.11 (m, 1 H), 3.64 (m, 2 H), 3.51 (t, *J* = 6.6 Hz, 2 H), 2.93 (br, *J* = 6.1 Hz, 1 H), 2.04–1.99 (m, 4 H), 1.58 (m, 2 H), 1.35–1.26 (m, 14 H), 0.89 (t, *J* = 6.5 Hz, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 130.2 (CH), 130.1 (CH), 124.5 (q, *J* = 280 Hz, CF_3), 72.3 (CH_2), 69.6 (q, *J* = 31 Hz, *C*HCF$_3$), 68.1 (CH_2), 32.2 (CH_2), 30.0 (CH_2), 29.7 (CH_2), 29.6 (CH_2), 29.5 (CH_2), 27.5 (CH_2), 27.2 (CH_2), 26.2 (CH_2), 22.6 (CH_2), 14.3 (CH_3).

^{19}F NMR (376 MHz, $CDCl_3$): δ = –78.28 (d, *J* = 6.9 Hz, CF_3).

MS (EI): *m*/*z* (%) = 324 (M^+, 3), 225 (8), 194 (30), 169 (27), 96 (97), 81 (100), 68 (99), 55 (95).

HRMS: *m*/*z* [M + H]$^+$ calcd for $C_{17}H_{32}F_3O_2$: 325.2354; found: 325.2361.

3-[3-(Benzyloxy)propoxy]-1,1,1-trifluoropropan-2-ol (1f)

IR (film): 3397, 2926, 2872, 1273, 1174, 1145 cm^{-1}.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.47–7.23 (m, 5 H), 4.50 (s, 2 H), 4.07 (m, 1 H), 3.62 (m, 6 H), 3.22 (br, 1 H), 1.89 (m, 2 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 138.4 (C), 128.6 (CH), 128.0 (CH), 127.9 (CH), 124.4 (q, *J* = 281 Hz, CF_3), 73.3 (CH_2), 69.5 (q, *J* = 31 Hz, *C*HCF$_3$), 69.3 (CH_2), 67.1 (CH_2), 53.7 (CH_2), 29.9 (CH_2).

^{19}F NMR (376 MHz, $CDCl_3$): δ = –78.16 (d, *J* = 6.3 Hz, CF_3).

MS (EI): *m*/*z* (%) = 278 (M^+, 25), 169 (24), 147 (35), 107 (97), 91 (100), 79 (34), 65 (33).

HRMS: *m*/*z* [M – H]$^+$ calcd for $C_{13}H_{16}F_3O_3$: 277.1052; found: 277.1042.

3-(Cyclohexyloxy)-1,1,1-trifluoropropan-2-ol (1g)

IR (film): 3415, 2936, 2860, 1452, 1275, 1140 cm^{-1}.

^{1}H NMR (500 MHz, $CDCl_3$): δ = 4.09 (m, 1 H), 3.70 (dd, *J* = 10.0, 5.0 Hz, 1 H), 3.63 (dd, *J* = 10.0, 5 Hz, 1 H), 3.33 (m, 1 H), 3.19 (br, 1 H), 1.89 (m, 2 H), 1.73 (m, 2 H), 1.52 (m, 1 H), 1.27 (m, 5 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 124.2 (q, *J* = 281 Hz, CF_3), 78.6 (CH), 69.3 (q, *J* = 31 Hz, *C*HCF$_3$), 65.1 (CH_2), 31.9 (CH_2), 31.7 (CH_2), 25.6 (CH_2), 23.8 (CH_2), 23.7 (CH_2).

^{19}F NMR (376 MHz, $CDCl_3$): δ = –78.21 (d, *J* = 7.0 Hz, CF_3).

MS (EI): *m*/*z* (%) = 212 (M^+, 27), 183 (34), 169 (45), 113 (56), 83 (100), 55 (66).

HRMS: *m*/*z* [M – H]$^+$ calcd for $C_9H_{14}F_3O_2$: 211.0946; found: 211.0942.

1,1,1-Trifluoro-3-(1-methylnonyloxy)propan-2-ol (1h)

IR (film): 3419, 2929, 2858, 1275, 1144, 909, 736 cm^{-1}.

^{1}H NMR (500 MHz, $CDCl_3$): δ = 4.08 (m, 1 H), 3.74–3.44 (m, 3 H), 3.29 (dd, *J* = 15.0, 6.5 Hz, 1 H), 1.56–1.26 (m, 14 H), 1.15 (d, *J* = 6.0 Hz, 3 H), 0.87 (t, *J* = 6.5 Hz, 3 H).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 124.2 (q, *J* = 280 Hz, CF_3), 77.0 (CH), 69.4 (q, *J* = 31 Hz, *C*HCF$_3$), 65.5 (CH_2), 36.3 (CH_2), 31.8 (CH_2), 29.6 (CH_2), 29.5 (CH_2), 29.2 (CH_2), 25.3 (CH_2), 22.6 (CH_3), 19.3 (CH_2), 14.0 (CH_3).

^{19}F NMR (376 MHz, $CDCl_3$): δ = –78.20 (d, *J* = 7.0 Hz, CF_3).

MS (EI): *m*/*z* (%) = 269 ([M – 1]$^+$, 4), 255 (22), 157 (98), 70 (64), 56 (100).

HRMS: *m*/*z* [M + H]$^+$ calcd for $C_{13}H_{26}F_3O_2$: 271.1885; found: 271.1872.

1,1,1-Trifluoro-3-(1-methylcyclohexyloxy)propan-2-ol (1i)

IR (film): 3447, 2934, 2861, 1274, 1175, 1143, 1123 cm^{-1}.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 4.07 (m, 1 H), 3.55 (m, 2 H), 3.09 (br, 1 H), 1.71–1.17 (m, 10 H), 1.14 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 124.4 (q, *J* = 280 Hz, CF_3), 74.7 (C), 69.4 (q, *J* = 30 Hz, *C*HCF$_3$), 57.9 (CH_2), 36.4 (CH_2), 36.0 (CH_2), 25.5 (CH_2), 25.4 (CH_2), 24.6 (CH_2), 22.0 (CH_3).

^{19}F NMR (376 MHz, $CDCl_3$): δ = –77.93 (d, *J* = 7.0 Hz, CF_3).

MS (EI): *m*/*z* (%) = 226 (M$^+$, 64), 211 (73), 197 (59), 183 (93), 170 (77), 115 (33), 97 (83), 81 (70), 71 (100), 55 (74).

HRMS: *m*/*z* [M – H]$^+$ calcd for $C_{10}H_{16}F_3O_2$: 225.1102; found: 225.1096.

1,1,1-Trifluoro-3-(octyloxy)propan-2-one (4a); Typical Procedure

To a soln of alcohol **1a** (188 mg, 0.77 mmol) in CH_2Cl_2 (0.2 mL) was added a 15% w/w Dess–Martin reagent in CH_2Cl_2 (24 mL, 3.68 g, 1.05 mmol). The mixture was stirred at r.t. for 19 h. The resultant cloudy soln was diluted with Et_2O (10 mL), washed with 10% aq $Na_2S_2O_3$ (10 mL), sat. $NaHCO_3$ soln, and brine, and dried ($MgSO_4$). After filtration and concentration, the residual oil was purified by flash column chromatography (hexane–Et_2O, 85:15) to afford **4a** (146 mg, 78%) as a colorless oil. The compound was obtained mainly as the hydrate form (keto/hydrate, 22:78).

^{1}H NMR (500 MHz, $CDCl_3$): δ = 3.60 (t, *J* = 7 Hz, 2 H), 3.62 (s, 2 H), 3.52 (t, *J* = 6.5 Hz, 2 H), 1.61 (m, 2 H), 1.27 (br, 12 H), 0.87 (t, *J* = 7 Hz, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 188.70 (q, *J* = 34.4 Hz, CO), 122.47 (q_{CF}, *J* = 284 Hz, CF_3 keto), 115.28 (q_{CF}, *J* = 290.6 Hz, CF_3 hydrate), 92.33 (q_{CCF}, *J* = 32.3 Hz, $C(OH)_2$), 72.80, 69.62, 31.77, 29.40, 29.31, 29.18, 25.86, 22.63, 14.07.

^{19}F NMR (282 MHz, $CDCl_3$): δ = –78.48 (s, COCF_3), –85.88 (s, $C(OH)_2CF_3$).

HRMS: *m*/*z* [M – H]$^+$ calcd for $C_{11}H_{18}F_3O_2$: 239.1252; found: 239.1259.

1,1,1-Trifluoro-3-[(*Z*)-tetradec-9-enyloxy]propan-2-one (4e)

Following a similar procedure starting from alcohol **1e**, with column chromatography purification (silica gel) gave TFMK **4e** (81% isolated yield). The chemical was obtained mainly in its hydrate form (keto/hydrate 20:80).

^{1}H NMR (300 MHz, $CDCl_3$): δ = 5.37–5.33 (m, 2 H), 4.50 (s, 2 H), 3.78 (s, 2 H), 3.62–3.54 (m, 4 H), 2.02 (m, 4 H), 1.63 (m, 2 H), 1.30 (br, 16 H), 0.90 (t, *J* = 6 Hz, 3 H).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 129.82 (CH), 129.68 (CH), 122.38 (q_{CF}, *J* = 285 Hz CF_3 hydrate), 92.23 (q_{CCF}, *J* = 32.4 Hz, $C(OH)_2$), 72.70 (CH_2O hydrate), 72.49 (CH_2O keto), 71.06 (CH_2O keto), 69.54 (CH_2O hydrate), 31.85, 29.09, 27.06, 25.77, 25.72, 22.24, 13.89.

^{19}F NMR (282 MHz, $CDCl_3$): δ = –78.47 (s, COCF_3), –85.89 (s, $C(OH)_2CF_3$).

HRMS: *m*/*z* [M + H]$^+$ calcd for $C_{17}H_{30}F_3O_2$: 323.2197; found: 323.2201.

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