Chemical modification of usnic acid
1. Reaction of (+)-usnic acid with perfluoroolefins*

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The reactions of the natural lichen metabolite, (+)-usnic acid, with a series of commercially available polyfluoroolefins (tetrafluoroethylene, chlorotrifluoroethylene, hexafluoropropene, perfluoro-2-methylpent-2-ene, and 1,2-dichlorooctafluorocyclohex-1-ene) afford its 7-*O*-polyfluoroalkyl and perfluorovinyl ethers.

Key words: (+)-usnic acid, perfluoroolefins, nucleophilic addition, nucleophilic substitution, phenols, organofluorine compounds, ethers.

Usnic acid (**1**) known from the mid-19th century was first isolated from the lichens *Usnea*, *Cladonia*, and some other.[1] The acid was found to exhibit a broad spectrum of biological activities including antiviral, antibiotic, analgesic, antituberculous, and insecticidal activities.[2—6] The described synthetic transformations of usnic acid (**1**) comprise the reaction of its carbonyl group with aromatic acid hydrazides to give hydrazones,[7] esterification of the phenolic groups with acid anhydrides and halides,[8,9] racemization, and alkaline hydrolysis.[1] Copper(II) and palladium(II) complexes with usnic acid and its derivatives have been extensively studied.[10,11] In view of the biological activity and relatively simple methods of isolation of usnic acid (**1**) from the plant raw materials, it appeared pertinent to extend the range of its synthetic transformations.

The present study deals with the reactions of usnic acid (**1**) with readily available polyfluoroolefins, namely, tetrafluoroethylene (**2**), chlorotrifluoroethylene (**3**), hexafluoropropene (**4**), perfluoro-2-methylpent-2-ene (**5**), and 1,2-dichlorooctafluorocyclohex-1-ene (**6**). It is known that the introduction of a fluorine atom or fluorine-containing groups often enhances the biological activity or the durability of action of bioactive agents. Effects of this type have been observed upon the introduction of the $CF{=}C(CF_3)X$ fragment ($X = CONEt_2$, $P(O)(OEt)_2$) into natural alkaloids[12] and the perfluorovinyl fragment into azoles.[13]

According to published data, the reactions of alcohols and phenols with perfluoroolefins[14] in the presence of bases in aprotic solvents give the products of nucleophilic substitution of the fluorine atom at the perfluoroolefin double bond. Presumably, the reaction of (+)-usnic acid (**1**) with terminal polyfluoroolefins **2—6** would follow a similar route, resulting in *O*-polyfluoroalkenyl derivatives.

Results and Discussion

We found that the reaction of compound **1** with polyfluoroolefins **2—4** in the presence of K_2CO_3 in DMF does not give fluorine substitution products, unlike the reactions of alcohols and phenols studied previously;[14] instead, compounds **7—9** resulting from the addition of the 7-OH group to the multiple bond of polyfluoroalkenes are formed (Scheme 1). Only in the case of olefin **4**, was compound **10** (a mixture of *cis*- and *trans*-isomers, ~1 : 1.6) detected as a minor product under these conditions. The overall yield of the mixture of compounds **9** and **10** (ratio 3 : 1) was 80—85%.

The reaction of acid **1** with perfluoroolefin **4** was used as an example to study the effect of the solvent and the base on the course of the reaction. In the NaH—THF and Et_3N—MeCN systems, the reaction results in a mixture of compounds **9** and **10** in different ratios with almost the same *cis*- to *trans*-isomer ratio for **10** ($Z/E \approx 1 : 1.6$). In the former case, the conversion of compound **1** was almost complete, whereas in the latter case, it amounted to 60—70%. The use of moist DMF (0.2% water) and K_2CO_3 gave predominantly compound **9** (yield 92%). In an-

* Dedicated to the memory of Academician N. N. Vorozhtsov on the 100th anniversary of his birth.

† Deceased.

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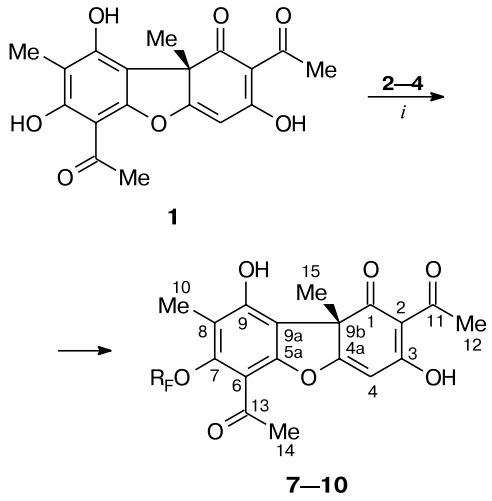
Scheme 1



i. K_2CO_3, DMF, 40—45 °C, 2—3 h.

Polyfluoroalkene	Product	R_F	Yield (%)
$F_2C{=}CF_2$ (**2**)	**7**	$^{17}\,^{16}CHF_2CF_2$—	94
$ClFC{=}CF_2$ (**3**)	**8**	$^{17}\,^{16}CHClFCF_2$—	87
$F_2C{=}CFCF_3$ (**4**)	**9**	$^{18}\,^{17}\,^{16}CF_3CHFCF_2$—	52
	10	$^{18}\,^{17}\,^{16}CF_3CF{=}CF$—	22 ($Z/E \approx 1 : 1.6$)

hydrous DMF compound **10** was formed in 76% yield, together with compounds **11** and **12** (Scheme 2). The last-mentioned fact can be attributed to partial dimerization, under the reaction conditions, of hexafluoropropene to perfluoro-4-methylpent-2-ene, which isomerizes in the presence of fluoride ions to give perfluoroolefin **5**, which is also involved in etherification.

Compounds **9** and **10** are apparently formed *via* the same intermediate carbanion **A** (Scheme 3). In the presence of traces of water, the protonation of this carbanion is the prevailing reaction route, leading to compound **9**. In the absence of water, anion **A** is stabilized through elimination of the fluoride ion to form a double bond (compound **10**).

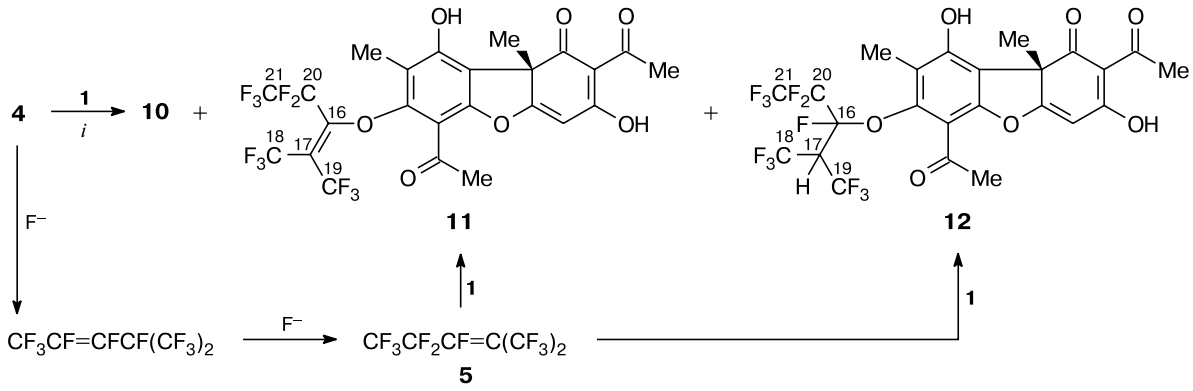
The reaction of internal perfluoroolefin **5** with usnic acid (**1**) obeys the same rules: addition product **12** is formed in the NaH—THF system, while substitution product **11** is obtained in anhydrous DMF in the presence of K_2CO_3. In moist DMF in the presence of K_2CO_3, compound **12** is the major product.

Since the fluorine atom at the double bond in compound **5** is less mobile than those in terminal perfluoroolefins, completion of the process requires longer time. In order to increase the efficiency, perfluoroolefin **5** was first converted into the ammonium salt **B** (Scheme 4). It has been shown previously[15] that the reaction of perfluoroolefin **5** with triethylamine in acetonitrile yields salt **B** in which the double-bond carbon atom is positively charged. A similar technique[16] has been used to introduce reagents with low nucleophilicity in the reaction with this salt. Indeed, the Et_3N—MeCN system proved to be efficient to carry out the reaction of equimolar amounts of perfluoroolefin **5** and (+)-usnic acid, resulting in a mixture of compounds **11** and **12** in 56 and 34% yields, respectively (see Scheme 4).

Interestingly, unlike compound **5**, the isomeric perfluoro-4-methylpent-2-ene does not react with usnic acid (**1**). Meanwhile, the use of the NaH—THF system affords the product of replacement of fluorine at the double bond, as was detected by ^{19}F NMR spectroscopy.

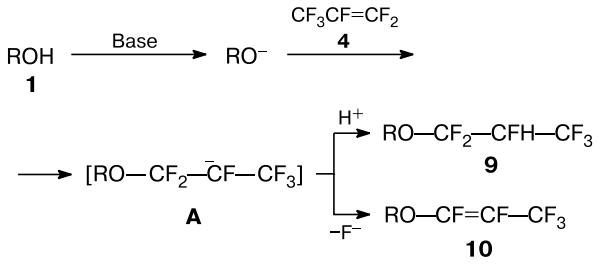
The reaction of (+)-usnic acid (**1**) with 1,2-dichlorooctafluorocyclohex-1-ene (**6**) in the presence of K_2CO_3 in anhydrous DMF gives the product of chlorine replacement at the double bond (compound **13**) and the product of addition to the double bond (compound **14**) (each formed in 34% yield), as was to be expected in line with reported data[17] (Scheme 5). The concentration of water

Scheme 2

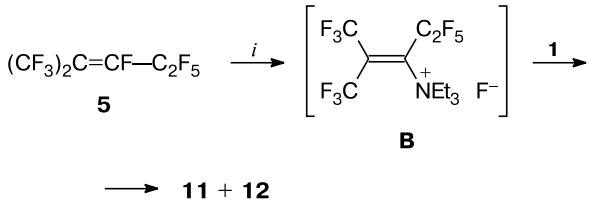


i. K_2CO, anhydrous DMF.

Scheme 3



Scheme 4



i. Et_3N, MeCN, 40—45 °C, 2 h.

admixture in DMF (in the presence of K_2CO_3) was found to influence the product ratio. When the water content is 0.2%, the reaction mainly gives compound **14** (yield 85%), whereas in anhydrous DMF compound **13** is formed with the same base (yield 94%). The nature of the base (KOH, NaH, Et_3N) is less significant for the reaction route.

Of the three hydroxy groups present in usnic acid (**1**), the OH group in position 7 (pK_a 10.7) participates in the reactions with perfluoroolefins **2**—**6**.[2] This may be inferred from the following facts. The ^1H NMR spectra of compounds **7**—**14** we prepared, unlike the ^1H NMR spectrum of usnic acid,[18] do not exhibit a proton signal at δ 13 for the OH group at C(7). In the ^{13}C NMR spectra, the most pronounced changes occur for the chemical shifts of C(6), C(7), C(9), and C(9a) signals, which are observed in lower fields with respect to these signals in the spectrum of the initial usnic acid. Note that according to published data,[19] treatment of usnic acid with chloroacetyl chloride in pyridine results in acylation of 7- and 9-OH groups.

In summary, we demonstrated the possibility of chemical modification of (+)-usnic acid (**1**) under the action of perfluoroolefins in the presence of bases and obtained a number of its polyfluoroalkylated and perfluoroalkenylated derivatives. It was also shown that these processes involve the OH group at the C(7) atom of usnic acid.

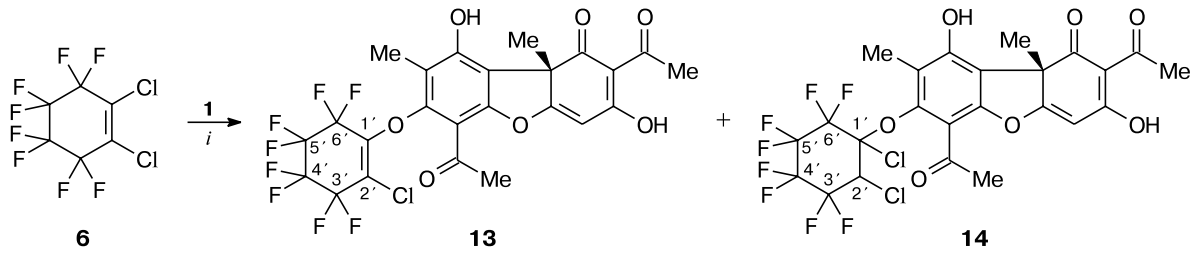
Experimental

^1H, ^{13}C, and ^{19}F NMR spectra were recorded on a Bruker WP 400 SY spectrometer (400, 100, and 188 MHz, respectively) relative to internal standards (HMDS and C_6F_6). The atom, numbering in the ^1H, ^{13}C, and ^{19}F NMR spectra of the obtained compounds corresponds to the numbering presented in the Schemes. UV spectra were measured on a Hewlett-Packard 8453 spectrophotometer, IR spectra were recorded on a Specord M-80 spectrometer (CCl_4), and GC/MS analysis (ionization electron energy 70 eV) was performed on a Finnigan MAT 8200 mass spectrometer and a chromatograph with mass-selective detector (Hewlett-Packard G 1800 A GCD). In the last-mentioned case, a 30000×0.25 mm column with a diphenyl- (5%) and dimethylsiloxane (95%) copolymer (HP-5) (0.25 μm layer) was used; helium was used as the carrier gas (1 mL min)$^{-1}$; the temperature of the injector was 280 °C. The temperature programming mode: 50 °C (2 min), then heating at a rate of 10 deg min^{-1} to 280 °C, and 280 °C (5 min). The conversion of usnic acid was monitored based on ^{19}F and ^1H NMR spectra. Commercial perfluoroolefins **2**—**5** were used. (+)-Usnic acid (**1**) was isolated from a mixture of lichens *Usnea*, $[\alpha]_D^{25}$ +441 (*c* 0.016, $CHCl_3$);[20] the physicochemical characteristics of the sample corresponded to published data.[21]

The UV spectra were not informative; IR spectra showed only an increase in the band intensities at 1069, 1118, and 1292 cm^{-1} and a very pronounced increase in the band intensities at 141 and 1187 cm^{-1}, caused by the appearance of C—F vibrations.

Reactions of usnic acid (1) with gaseous perfluoroolefins (general procedure). Perfluoroolefin (tetrafluoroethylene (**2**), trifluorochloroethylene (**3**), or hexafluoropropene (**4**)) (~500—600 mL) was passed with stirring at 40—45 °C for 3—4 h through a mixture of (+)-usnic acid (**1**) (0.3 g) and K_2CO_3 (0.3 g) in dry DMF (10 mL). The reaction mixture was poured into water (300 mL), acidified with 5% HCl, and left

Scheme 5



i. K_2CO_3, DMF, 40—45 °C, 2—3 h.

for 0.5 h for coarsening of the finely dispersed solid initially precipitated. The precipitate was filtered off, washed with water (100 mL), and dried in air (24 h). The compound was purified by chromatography on a column with silica gel (CH_2Cl_2 as the eluent).

2,6-Diacetyl-3,9-dihydroxy-8,9b-dimethyl-7-(1′,1′,2′,2′-tetrafluoroethoxy)-9b*H*-dibenzofuran-1-one (7). Yield 94%, m.p. 186—188 °C (from CH_2Cl_2). UV (EtOH), λ_{max}/nm (ε): 230 (55444), 201 (44159), 284 (50338). ^{1}H NMR ($CDCl_3$), δ: 18.82 (C(3)OH); 11.00 (C(9)OH); 5.98 (tt, H(17), $^2J_{H,F}$ = 55 Hz, $^3J_{H,F}$ = 5 Hz); 5.95 (H(4)); 2.64 (3 H(12), 3 H(14)); 2.07 (3 H(10)); 1.79 (3 H(15)). ^{19}F NMR ($CDCl_3$), δ: 75.0 (s, 2 F, F(16)); 26.0 (d, 2 F, F(17), J = 53.1 Hz). ^{13}C NMR ($CDCl_3$), δ: 201.8, 201.7, 200.2 (C(11), C(13), C(1)); 191.6 (C(3)); 179.2 (C(4a)); 163.8 (C(7)); 157.4 (C(5)); 155.1 (C(5a)); 116.7 (C(16), $^1J_{C,F}$ = 272.7 Hz, $^2J_{C,F}$ = 29.3 Hz); 109.2 (C(8)); 107.5 (C(17), $^1J_{C,F}$ = 254.4 Hz, $^2J_{C,F}$ = 40.1 Hz); 105.1 (C(2)); 103.8 (C(9a)); 101.4 (C(6)); 98.2 (C(4)); 58.9 (C(9b)); 31.8 (C(10)); 31.6 (C(14)); 27.8 (C(12)); 7.4 (C(15)). High-resolution MS, found: m/z 444.08337 $[M]^+$. $C_{20}H_{16}F_4O_7$. Calculated: M = 444.08320.

2,6-Diacetyl-3,9-dihydroxy-8,9b-dimethyl-7-(2′-chloro-1′,1′,2′-trifluoroethoxy)-9b*H*-dibenzofuran-1-one (8). Yield 87%, m.p. 137—138 °C (from CH_2Cl_2). UV (EtOH), λ_{max}/nm (ε): 201 (49227), 265 (42529). ^{1}H NMR ($CDCl_3$), δ: 18.82 (C(3)OH); 11.00 (C(9)OH); 6.34 (H(17), $^1J_{H,F}$ = 36.0 Hz, $^3J_{H,F}$ = 5 Hz); 5.95 (H(4)); 2.64 (3 H(12), 3 H(14)); 2.18 (3 H(10)); 1.78 (3 H(15)). ^{19}F ($CDCl_3$), δ: 78.9 (m, 2 F, F(16)); 9.2 (dt, F(17), $J_{F,H}$ = 48 Hz, $J_{F,H}$ = 10 Hz). ^{13}C NMR ($CDCl_3$), δ: 201.7 (C(11)); 197.5 (C(13)); 194.8 (C(1)); 191.5 (C(3)); 179.0 (C(4a)); 154.5 (C(7)); 152.2 (C(9)); 145.2 (C(5a)); 119.3 (C(8)); 118.5 (C(16), $^1J_{C,F}$ = 273.3 Hz, $^2J_{C,F}$ = 26.1 Hz); 113.5 (C(2)); 111.1 (C(9a)); 105.1 (C(6)); 98.4 (C(4)); 84.8 (C(17), $^1J_{C,F}$ = 201.4 Hz, $^2J_{C,F}$ = 35.6 Hz); 59.0 (C(9b)); 31.7 (C(10)); 31.3 (C(14)); 27.6 (C(12)); 9.4 (C(15)). High-resolution MS, found: m/z 460.05328 $[M]^+$. $C_{20}H_{16}ClF_3O_7$. Calculated: M = 460.05365.

2,6-Diacetyl-3,9-dihydroxy-8,9b-dimethyl-7-(1′,1′,2′,3′,3′,3′-hexafluoropropoxy)-9b*H*-dibenzofuran-1-one (9). Yield 52%, m.p. 96—98 °C (from CH_2Cl_2). Found (%): F, 22.30. $C_{21}H_{16}F_6O_7$. Calculated (%): F, 23.08. UV (EtOH), λ_{max}/nm (ε): 213 (37573); 265 (32953). ^{1}H NMR ($CDCl_3$), δ: 18.82 (C(3)OH); 11.03 (C(9)OH); 10.61 (dd, H(17), $^1J_{H,F}$ = 55.0 Hz, $^3J_{H,F}$ = 6 Hz); 5.95 (H(4)); 2.64 (3 H(12), 3 H(14)); 2.17 (3 H(10)); 1.79 (3 H(15)). ^{19}F NMR ($CDCl_3$), δ: 87.4 (s, 3 F, F(18)); 84.5 (s, 2 F, F(16)); −49.1 (dd, 1 F, F(17), J = 43.5 Hz, J = 12.2 Hz). ^{13}C NMR ($CDCl_3$), δ: 201.5 (C(11)); 197.5 (C(13)); 194.8 (C(1)); 191.6 (C(3)); 179.2 (C(4a)); 154.5 (C(7)); 152.2 (C(9)); 152.7 (C(5)); 144.9 (C(5a)); 120.2 (C(16), $^1J_{C,F}$ = 266.9 Hz, $^2J_{C,F}$ = 29.6 Hz); 119.8 (C(8)); 119.54 (C(18), $^1J_{C,F}$ = 257.0 Hz, $^2J_{C,F}$ = 29.6 Hz); 111.0 (C(2)); 110.55 (C(9a)); 105.0 (C(6)); 98.2 (C(4)); 85.6 (C(17), $^1J_{C,F}$ = 201.0 Hz, $^2J_{C,F}$ = 34.6 Hz); 58.9 (C(9b)); 31.9 (C(10)); 31.5 (C(14)); 27.7 (C(12)); 8.0 (C(15)). High-resolution MS, found: m/z 494.06810 $[M]^+$. $C_{21}H_{16}F_6O_7$. Calculated: M = 494.08001.

2,6-Diacetyl-3,9-dihydroxy-8,9b-dimethyl-7-(1′,2′,3′,3′,3′-pentafluoroprop-1′-enyloxy)-9b*H*-dibenzofuran-1-one (10). Yield 22%. UV (EtOH), λ_{max}/nm (ε): 230 (55444), 201 (44159), 284 (50338). ^{1}H NMR ($CDCl_3$), δ: 18.82 (C(3)OH); 11.03 (C(9)OH); 5.85 (H(4)); 2.60 (H(12), H(14)); 2.19 (H(10)); 1.84 (H(15)). ^{19}F NMR for *cis*-isomer ($CDCl_3$), δ: 89.6 (s, 3 F, F(18)); 84.5 (dd, 1 F, F(16), J = 146.4 Hz, J = 2.4 Hz); −22.4 (d, 1 F, F(17), J = 8.3 Hz). ^{19}F NMR for *trans*-isomer ($CDCl_3$), δ: 90.2 (t, 3 F, F(18), J = 4.1 Hz); 73.1 (dd, 1 F, F(16), J = 160.8 Hz, J = 12.6 Hz); −18.6 (d, 1 F, F(17), J = 115.0 Hz). ^{13}C NMR ($CDCl_3$), δ: 201.5 (C(11)); 197.6 (C(13)); 194.7 (C(1)); 191.5 (C(3)); 179.3 (C(4a)); 154.5 (C(7)); 152.3 (C(9)); 145.0 (C(5a)); 119.3 (C(8)); 118.4 (C(18), $^1J_{C,F}$ = 281.9 Hz, $^2J_{C,F}$ = 25.5 Hz); 116.7 (C(16), $^1J_{C,F}$ = 273.5 Hz, $^2J_{C,F}$ = 21.6 Hz); 113.3 (C(2)); 111.1 (C(9a)); 105.1 (C(6)); 98.38 (C(4)); 84.8 (C(17), $^1J_{C,F}$ = 201.4 Hz, $^2J_{C,F}$ = 35.6 Hz); 59.0 (C(9b)); 31.7 (C(10)); 31.3 (C(14)); 27.6 (C(12)); 9.0 (C(15)).

Reaction of (+)-usnic acid (1) with liquid perfluoroolefins (general procedure). A mixture of (+)-usnic acid (**1**) (0.3 g), Et_3N (0.3 g), and polyfluoroolefin **5** or **6** (1 g) in dry MeCN (10 mL) was stirred for 3—4 h at 40—45 °C, cooled, and poured into water. The mixture was acidified with 5% HCl and extracted with CH_2Cl_2. The extract was dried with $CaCl_2$, the solvent was distilled off, and the product was purified by column chromatography on silica gel (CH_2Cl_2 as the eluent).

A similar procedure was used to carry out the reactions of perfluoroolefins **4**—**6** in the presence of K_2CO_3 in anhydrous DMF.

2,6-Diacetyl-3,9-dihydroxy-8,9b-dimethyl-7-(perfluoro-2′-methylpent-2′-en-3′-yloxy)-9b*H*-dibenzofuran-1-one (11). Yield 56%, m.p. 203—204 °C. UV (EtOH), λ_{max}/nm (ε): 231 (41255), 283 (33410). ^{1}H NMR ($CDCl_3$), δ: 18.82 (C(3)OH); 11.00 (C(9)OH); 5.96 (H(4)); 2.66 (H(12), H(14)); 2.15 (H(10)); 1.74 (H(15)). ^{19}F NMR ($CDCl_3$), δ: 110.4 (3 F, F(18), $J_{F(20),F(18)}$ = 20.4 Hz, $J_{F(19),F(18)}$ = 10.3 Hz); 106.4 (t, 3 F, F(19), J = 10.3 Hz); 81.8 (q, 3 F, F(21), J = 6.1 Hz); 56.2 (2 F, F(20), $J_{F(20),F(18)}$ = 20.4 Hz). High-resolution MS, found: m/z 624.06510 $[M]^+$. $C_{24}H_{15}F_{11}O_7$. Calculated: M = 624.06419. Fragment ion, found: m/z 604.06350 $[M - HF]^+$. $C_{24}H_{14}F_{10}O_7$. Calculated: M − HF = 604.05797.

2,6-Diacetyl-3,9-dihydroxy-8,9b-dimethyl-7-[2′-(H)-perfluoro-2′-methylpent-3′-yloxy]-9b*H*-dibenzofuran-1-one (12). Yield 34%, m.p. 194—196 °C. ^{1}H NMR ($CDCl_3$), δ: 18.81 (s, C(3)OH); 10.99 (s, C(9)OH); 5.94 (H(4)); 4.75 (m, H(17)); 2.63 (H(12), H(14)); 2.05 (H(10)); 1.72 (H(15)). ^{19}F NMR ($CDCl_3$), δ: 101.9 (s, 6 F, F(18), F(19)); 83.4 (s, 3 F, F(21)); 52.0 (s, 1 F, F(16)); 42.2 (s, 2 F, F(20)). High-resolution MS, found: m/z 624.06510 $[M - HF]^+$ (fragment ion). $C_{24}H_{15}F_{11}O_7$. Calculated: M − HF = 624.06419.

2,6-Diacetyl-3,9-dihydroxy-8,9b-dimethyl-7-(2′-chlorooctafluorocyclohex-1′-en-1′-yloxy)-9b*H*-dibenzofuran-1-one (13). Yield 34%, m.p. 195—197 °C (from CH_2Cl_2). UV (EtOH), λ_{max}/nm (ε): 201 (39905), 227 (39815), 268 (33560). ^{1}H NMR ($CDCl_3$), δ: 18.8 (C(3)OH); 11.0 (C(9)OH); 5.94 (H(4)); 2.63 (H(12), H(14)); 2.06 (H(10)); 1.72 (H(15)). ^{19}F NMR ($CDCl_3$), δ: 54.5, 53.8 (AB-system, 2 F, F(6′), $J_{F,F}$ = 301 Hz); 49.2, 48.4 (AB-system, 2 F, F(3′), $J_{F,F}$ = 289 Hz); 42.2 (d, 2 F, F(4′), F(5′), J = 301 Hz); 30.3 (d, 2 F, F(4′), F(5′), J = 301 Hz). ^{13}C NMR ($CDCl_3$), δ: 201.8 (C(11)); 201.6 (C(13)); 197.9 (C(1)); 191.5 (C(3)); 178.4 (C(4a)); 163.6 (C(7)); 155.1 (C(9)); 154.8 (C(5a)); 118.3 (C(2′), $^2J_{C,F}$ = 40.8 Hz); 118.1 (C(1′), $^2J_{C,F}$ = 40.8 Hz); 110.2 (C(8)); 109.4 (C(6′), $^1J_{C,F}$ = 261.1 Hz, $^2J_{C,F}$ = 24.5 Hz); 107.4 (C(5′), $^1J_{C,F}$ = 261.1 Hz, $^2J_{C,F}$ = 24.5 Hz); 107.4 (C(4′), $^1J_{C,F}$ = 261.1 Hz, $^2J_{C,F}$ = 24.5 Hz); 108.3 (C(3′), $^1J_{C,F}$ = 253.1 Hz, $^2J_{C,F}$ = 24.5 Hz); 105.1 (C(2)); 103.8 (C(9a)); 101.3 (C(6)); 98.5 (C(4)); 58.7 (C(9b)); 32.0 (C(10)); 31.8 (C(14)); 27.7 (C(12)); 8.3 (C(15)). High-resolu-

tion MS, found: m/z 602.03518 $[M]^+$. $C_{24}H_{15}ClF_8O_7$. Calculated: M = 602.05179.

2,6-Diacetyl-3,9-dihydroxy-8,9b-dimethyl-7-(1′,2′-dichloro-3′,3′,4′,4′,5′,5′,6′,6′-octafluorocyclohexyloxy)-9b*H*-dibenzofuran-1-one (14). Yield 34%, m.p. 201—202 °C (from CH_2Cl_2). ^{1}H NMR ($CDCl_3$), δ: 18.8 (C(3)OH); 11.0 (C(9)OH); 7.35 (H(2′)); 5.94 (H(4)); 2.63 (H(12), H(14)); 2.06 (H(10)); 1.72 (H(15)). ^{19}F NMR ($CDCl_3$), δ: 50.1, 36.9 (AB-system, 2 F, F(3′), $J_{F,F}$ = 325 Hz); 49.9, 37.9 (AB-system, 2 F, F(4′), $J_{F,F}$ = 345 Hz); 51.6, 38.6 (AB-system, 2 F, F(5′), $J_{F,F}$ = 350 Hz); 50.9, 26.7 (AB-system, 2 F, F(6′), $J_{F,F}$ = 282.4 Hz).

Reaction of (+)-usnic acid (1) with perfluoroolefins in the NaH—THF system (general procedure). Sodium hydride (0.04 g) was added with stirring at 0—5 °C to a solution of (+)-usnic acid (**1**) (0.3 g) in dry THF (15 mL), and the mixture was stirred for 20 min at this temperature. Then the temperature was raised to 40—45 °C and perfluoroolefin **5** or **6** (1 g) was added (or hexafluoropropene **4** was passed). The reaction mixture was stirred for 3—4 h, poured into water (300 mL), acidified with 5% HCl, and extracted with CH_2Cl_2, and the extract was dried with $CaCl_2$. After evaporation of the solvent, the residue was purified by column chromatography on silica gel (CH_2Cl_2 as the eluent).

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