

Synthesis of perfluoro crown ethers: a new class of cyclic fluorocarbons

Wen-Huey Lin, Webb I. Bailey, Jr. and Richard J. Lagow*

Department of Chemistry, The University of Texas, Austin, Texas 78712

Abstract: The first perfluoro crown ethers, perfluoro-18-crown-6, perfluoro 15-crown-5 and perfluoro 12-crown-4, have been prepared by carefully controlled elemental fluorination. Although they are weaker bases, crown ethers are materials which will have a number of applications.

Perfluoro crown ethers have been synthetically inaccessible by conventional reactions of fluorocarbons and outside the capabilities of synthesis by fluorination using selective fluorination reagents. Examples of this potentially useful class of macrocycles have been prepared recently in our laboratory. These syntheses have been accomplished using the broadly applicable techniques for controlling reactions of elemental fluorine (LaMar) developed in our laboratory and the reactions were conducted in the previously described cryogenic fluorination reactor.¹

Perfluoro crown ethers are expected to be unusually stable. The reactions to produce perfluoro 18-crown-6, perfluoro 15-crown-5 and perfluoro 12-crown-4 are illustrated in Figure 1.

The starting hydrocarbon crown ether was purified by distillation and recrystallization. In a typical experiment, 0.81 g 18-crown-6 and 2.09 g NaF were ground to a fine powder and mixed well in a dry box. We found for these experiments that several factors influenced the yields obtained: the surface area exposed to fluorine, the reaction

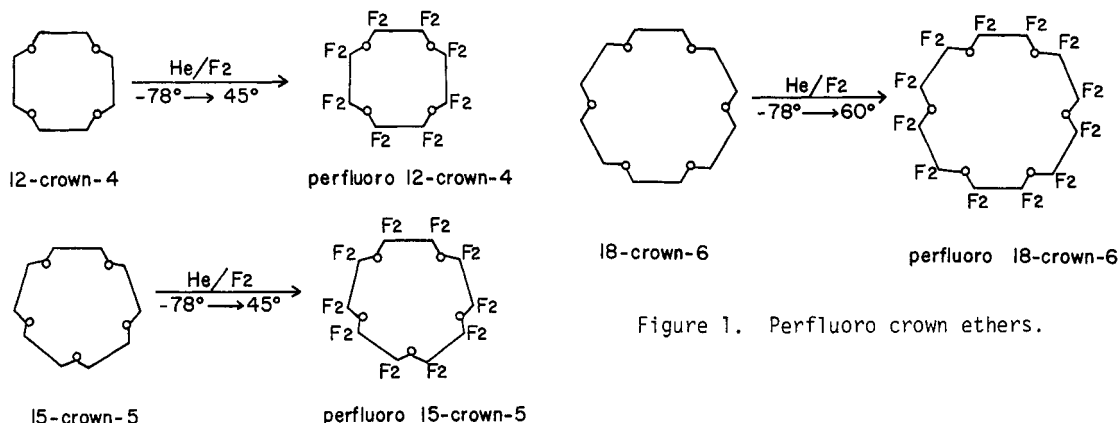


Figure 1. Perfluoro crown ethers.

temperatures, the reaction time, and the fluorination conditions. But the surface area variable was particularly important. To increase the surface area, sodium fluoride was used as a solid support upon which the starting crown ether was coated. A second function of this sodium fluoride was to react with the hydrogen fluoride produced as the reaction proceeds.

The mixture was placed in a nickel boat and loaded into a fluorination reactor. A trap was placed after the reactor which was used to collect the volatile products. After a He purge was maintained for several hours, the reactor and trap were cooled to -78°C . The fluorination reaction was started and followed the conditions shown in Table I. After the reaction, He was passed through the reactor to sweep F_2 from the system.

The volatile products produced were transferred from the -78°C trap to a vacuum line for fractionation. Fractions were obtained that stopped at -23°C and -78°C . The -23°C fraction was further separated into three components using a gas chromatograph with a fluorosilicone column.

The major component was identified as perfluoro 18-crown-6. Perfluoro 18-crown-6 was a volatile colorless crystalline solid, mp 34°C , obtained in 33.5% yield (0.715 g based on starting 18-crown-6) which could be easily sublimed. The elemental analyses were consistent with $\text{C}_{12}\text{F}_{24}\text{O}_6$ (Calcd: %C, 20.71; %F, 65.50. Found: %C, 20.90; %F, 65.35). The vapor phase IR spectrum exhibited bands at 1240(vs), 1220(vs), 1140(vs) and $730(\text{m})\text{ cm}^{-1}$. The ^{19}F NMR (C_6F_6 solution) contained a singlet at -91.0 ppm from external CFCl_3 . The ^{13}C NMR (C_6F_6 solution) also contained a singlet which was observed at 114.9 ppm from external TMS. The mass spectrum (with the spectrometer cooled to ambient temperature) gave no parent peak but m/e of 677 was observed which corresponded to the molecular ion minus one fluorine. The remaining two fractions from the GC separation were identified as $\text{CF}_3\text{O}(\text{CF}_2\text{CF}_2\text{O})_4\text{CF}_3$ (40 mg) and $\text{CF}_3\text{CF}_2\text{O}(\text{CF}_2\text{CF}_2\text{O})_4\text{CF}_3$ (22 mg) (see Table II). These reaction by-products resulted from the fragmentation of the ring system to produce the straight chain perfluoro polyethers.

The preparation of 15-crown-5 and 12-crown-4 were performed in a similar manner. The fluorination parameters used are listed in Table III. The properties and characterization of perfluoro 15-crown-5 and perfluoro 12-crown-4 are listed in Table IV.

Perfluorinated derivatives of hydrocarbon compounds usually exhibit different properties than their hydrocarbon analogues. The perfluoro crown ethers are markedly more volatile than the hydrocarbon products. One would expect the dimensions of the pocket size to change. A decrease in the basicity of the crown ether would also be predicted and a key question is whether the perfluoro crown ethers can coordinate metals and organometallic species? This interaction, which is expected to be much weaker, is under study. The perfluoro analog has approximate C_2 symmetry, unlike 18-crown-6 which has C_1 symmetry, as illustrated with a view looking through the cavity of the molecule.

Table I. Fluorination parameters for 18-crown-6.

Time (hrs.)	He (cc/min)	F ₂ (cc/min)	Temp. (°C)
16	60	0	-78
23	40	1.0	-78
24	20	1.0	-78
24	10	1.0	-78
24	10	3.0	-78
24	0	1.0	-78
36	0	2.0	-78
29	0	2.0	RT
24	0	2.0	45
47	0	2.0	60
24	60	0	60
295			

Table III. Fluorination parameters for 15-crown-5 and 12-crown-4.

Time (hrs.)	He (cc/min)	F ₂ (cc/min)	Temp. (°C)
<u>15-crown-5:</u>			
18	60	0	-78
25	40	1.0	-78
24	20	1.0	-78
24	10	1.0	-78
29	10	3.0	-78
40	0	1.0	-78
43	0	2.0	-78
29	0	2.0	RT
24	0	2.0	45
24	60	0	45
280			
<u>12-crown-4:</u>			
20	60	0	-78
22	40	1.0	-78
25	20	1.0	-78
24	10	1.0	-78
24	10	3.0	-78
33	0	1.0	-78
37	0	2.0	-78
24	0	2.0	RT
27	0	2.0	45
24	60	0	45
260			

Table II. Characterizations of straight chain perfluoropolyethers.

Compound (highest m/e in mass spec)	Assigned ¹⁹ F Chemical Shift in ppm (vs Ext. CFC1 ₃)	Relative Intensities obs. theor.	
1. CF ₃ OCF ₂ CF ₂ OCF ₂ CF ₂ OCF ₃			
a b c c b a	a = -58.5	1.5	1.5
367 (C ₆ F ₁₃ O ₃ , P-F)	b = -93.2	1.1	1.0
	c = -91.1	1.0	1.0
2. CF ₃ CF ₂ OCF ₂ CF ₂ OCF ₂ CF ₂ OCF ₃			
a b c c c c d	a = -89.7	1.5	1.5
417 (C ₇ F ₁₅ O ₃ , P-F)	b = -93.0	1.0	1.0
	c = -91.0	4.4	4.0
	d = -58.3	1.4	1.5
3. CF ₃ CF ₂ OCF ₂ CF ₂ OCF ₂ CF ₂ OCF ₂ CF ₃			
a b b b b b a	a = -89.9	1.0	1.0
467 (C ₈ F ₁₇ O ₃ , P-F)	b = -91.0	2.1	2.0
4. CF ₃ O[CF ₂ CF ₂ OCF ₂ CF ₂ OCF ₂ CF ₂ O]CF ₃			
a b c c c c b a	a = -58.1	1.5	1.5
483 (C ₈ F ₁₇ O ₄ , P-F)	b = -92.0	1.0	1.0
	c = -90.9	2.2	2.0
5. CF ₃ CF ₂ O[CF ₂ CF ₂ OCF ₂ CF ₂ OCF ₂ CF ₂ O]CF ₃			
a b c c c c c d	a = -89.6	1.2	1.5
(533 (C ₉ F ₁₉ O ₃ , P-F)	b = -92.7	1.0	1.0
	c = -90.8	5.2	6.0
	d = -58.0	1.2	1.5
6. CF ₃ O[CF ₂ CF ₂ OCF ₂ CF ₂ OCF ₂ CF ₂ OCF ₂ CF ₂ O]CF ₃			
a b c c c c c b a	a = -58.3	1.5	1.5
599 (C ₁₀ F ₂₁ O ₅ , P-F)	b = -93.0	1.0	1.0
	c = -91.0	2.9	3.0
7. CF ₃ CF ₂ O[CF ₂ CF ₂ OCF ₂ CF ₂ OCF ₂ CF ₂ OCF ₂ CF ₂ O]CF ₃			
a b c c c c c c c d	a = -89.4	1.3	1.5
599 (C ₁₀ F ₂₁ O ₅ , P-CF ₃)	b = -92.7	1.0	1.0
	c = -90.6	8.0	8.0
	d = -58.0	1.4	1.5

Table IV. Properties and characterization of perfluoro 15-crown-5 and perfluoro 12-crown-4.

	15-crown-5	12-crown-4
Boiling Point, °C	146°	118°
Elemental Analysis	$C_{10}F_{20}O_5$	$C_8F_{16}O_4$
Calcd.	%C, 20.71; %F, 65.50	%C, 20.71; %F, 65.50
Found	%C, 20.90; %F, 65.04	%C, 20.90; %F, 65.18
IR (vapor phase) cm^{-1}	1250(s), 1228(vs), 1158(vs), 745(m)	1260(vs), 1188(vs), 1160(vs), 1080(m), 825(m), 745(br)
NMR (neat liquid)	^{19}F - singlet -91.8 ppm (ext. $CFCl_3$) ^{13}C - singlet 114.9 ppm (ext. TMS)	^{19}F - singlet -90.0 ppm (ext. $CFCl_3$) ^{13}C - singlet 114.9 ppm (ext. TMS)
Mass Spectrum, m/e	580 ($C_{10}F_{20}O_5$, P)	445 ($C_8F_{16}O_4$, P-F)

Single crystals have been grown of 18-crown-6 and preliminary structural information indicates that the ring is puckered in a manner so that oxygen is exposed and projected toward a metal coordination site.² The effects of perfluorinating 18-crown-6 show up very well in the shortened C-O bonds and lengthened C-C bonds. The average C-O bond length in perfluoro 18-crown-6 [1.376(7)Å] is shorter than the average C-O bond length in 18-crown-6 [1.411(8)Å]. In addition to the possibility of serving normal functions as macrocyclic ligands, the compounds are of interest in the biomedical and oxygen carrier areas for they are definitely physiologically compatible with human and other mammalian tissue.³

This synthetic breakthrough opens the possibility of preparation of many novel crown ether systems as well as the synthesis of perfluoro cryptans. Such ligands should be much less subject to chemical attack or thermal degradation.

Acknowledgement

We are grateful for support of this work by the Air Force Office of Scientific Research (AFOSR-82-0197 and AFOSR-87-0016).

REFERENCES

1. Margrave, J.L.; Lagow, R.J., *Progress in Inorganic Chemistry*, 1979, 26, 161.
2. Simonsen, S.H.; Larsen, S.B.; Lin, W.H.; Bailey, W.I., Jr.; Lagow, R.J., to be published.
3. Lagow, R.J.; Lin, W.H.; Clark, L.C., to be published.