Synthesis of *Gem*-Dinitroethyl Trifluoromethyl Ethers with Sulfur Tetrafluoride

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The synthesis of trifluoromethoxy-*gem*-dinitroethyl compounds of the type, $RC(NO_2)_2CH_2OCF_3$ where R = $—F$, $—NO_2$, $—CH_3$, and $—CH_2OCF_3$, is reported for the first time. The compounds were prepared by treatment of the appropriate dinitroethanol with carbonyl fluoride, followed by reaction of intermediate fluoroformate with sulfur tetrafluoride. The physical constants of the fluoroformates and trifluoromethyl ethers are reported.

Over the past several years, we have generated significant data on the synthesis, characterization, and evaluation of organic fluoronitro compounds (*4, 5*). To relate structure to physical properties in this class of compounds, it was necessary to prepare additional representative structures. Thus, we undertook to devise a general synthetic route and to prepare a number of compounds for evaluation, such as $RC(NO_2)_2CH_2OCF_3$ where R = $—NO_2$, $—F$, $—CH_3$, and $—CH_2OCF_3$. An alternative approach to prepare fluoronitro trifluoromethyl ethers by basic reduction of 2,2,2-trinitroethyl trifluoromethyl ether was unsuccessful.

We wish to report that dinitroethyl trifluoromethyl ethers can be prepared in good yields (50–70%) by treating the corresponding alcohol with carbonyl fluoride, Reaction 1, and subsequent reaction of the fluoroformate with sulfur tetrafluoride, Reaction 2.

$$RC(NO_2)_2CH_2OH \xrightarrow[\substack{NaF \\ (1)}]{COF_2} RC(NO_2)_2CH_2OCOF \xrightarrow[\substack{HF \\ (2)}]{SF_4} RC(NO_2)_2CH_2OCF_3$$

$$R = —NO_2,\ —F,\ —CH_3,\ —CH_2OCF_3$$

Hasek et al. (*3*) were able to prepare a large number of trifluoromethyl compounds from the corresponding carboxylic acids or esters with sulfur tetrafluoride. Sheppard (*6*) reported the synthesis of a number of aromatic trifluoromethyl ethers by treating the appropriate phenol with carbonyl fluoride or phosgene, followed by reaction with sulfur tetrafluoride and hydrogen fluoride at high temperatures. In subsequent work, Aldrich and Sheppard (*1*) prepared a number of aliphatic trifluoromethyl ethers by the same procedure. However, the preparation of alkyl trifluoromethyl ethers by this method was practical only when the R groups on the β-carbon were electron-withdrawing substituents, i.e., F, Cl, Br, OCOF, and OCF_3. In other work on the synthesis of alkyl trifluoromethyl ethers, the nitro group was not suggested as an acceptable electron-withdrawing group. Without these electron-withdrawing groups, intramolecular reaction probably occurs, producing carbon dioxide, hydrogen fluoride, and substituted ethylene.

When we first attempted to obtain the fluoroformate of 2,2,2-trinitroethanol with carbonyl fluoride and pyridine as base, a 64% yield of the corresponding carbonate, $[C(NO_2)_3CH_2O]_2C = O$, was obtained. However, when sodium fluoride was used as base, a 77% yield of the desired fluoroformate was obtained.

The preparation of 2,2,2-trinitroethyl trifluoromethyl ether, II, from the fluoroformate was run using various temperatures to optimize yields. The sulfur tetrafluoride reaction at 150–175°C has been reported. At these temperatures, however, we would expect the nitro compounds to decompose. By lowering the reaction temperature and increasing the reaction time, we were able to extend the work of Sheppard (*6*) to include the preparation of dinitroethyl trifluoromethyl ethers. We found that at temperatures above 100°C, the nitrofluoroformate decomposed, and at less than 70°C, little or no reaction occurred. However, when the reaction was held at 80–90°C for 64 hr, a 45% yield of II was obtained.

Table I shows the preparation and physical properties of the intermediate *gem*-dinitroethyl fluoroformates. As expected, the volatility of the fluoroformates decreased as the size of the R group increased. The fluoroformates had an acrid odor and decomposed slowly in moist air or on standing in glass containers.

Table II shows the preparation, and Table III the physical properties of the *gem*-dinitroethyl trifluoromethyl ethers. Again, the volatility of the trifluoromethyl ethers decreased as the size or hydrogen-bonding character of the R group increased. The trifluoromethyl ethers were very stable compounds. For instance, IV could be heated at 100°C for 24 hr with sulfuric acid or with other Lewis acid catalysts, such as $SbCl_5$ or $FeCl_3$, without decomposition.

Experimental

Melting points and boiling points are uncorrected. Elemental analyses were performed by E. M. McCarthy; nmr spectra were run on a Varian HA-100 spectrometer. An F+M Model 500 gas chromatograph equipped with a thermal conductivity detector was used for all glpc analyses. The infrared spectra were recorded with a Perkin-Elmer 237 infrared spectrophotometer.

Caution: Carbonyl fluoride and sulfur tetrafluoride are highly reactive and highly toxic gases; $LD_{50} \sim 10–20$ ppm. Toxicities and mode of action are similar to those of phosgene. Both reagents react with water to liberate hydrogen fluoride; therefore, care must be taken to avoid hydrogen fluoride burns when these chemicals are used. The reactions should be performed in a well-ventilated hood with shields, masks, and rubber gloves. Since many fluoronitro compounds are toxic to varying degrees, care must be taken to avoid inhalation or contact with compounds I–VIII.

General preparation of fluoroformates. The appropriate nitroalcohol and sodium fluoride were sealed in a 300-ml stainless-steel autoclave, evacuated to less than 1 mm, and cooled to −78°C using a Dry Ice-acetone bath. Carbonyl fluoride (Peninsular ChemResearch, Gainesville, Fla.) in excess was distilled into the reaction vessel. The autoclave was sealed and rocked gently at ambient tem-

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Table I. Preparation of *Gem*-Dinitroethyl Fluoroformates, $RC(NO_2)_2CH_2OCOF$[a]

Compound[b]	Moles			Time,	Yield,	Bp, °C	Spectral properties[c] of nmr data	
R =	Alcohol	COF_2	NaF	hr	%	(mm)	δ	φ^*
I, $-NO_2$	0.10	0.77	0.10	72	77	38° (0.7)	4.46 (s, CH_2)	19.0 (s, COF)
III, $-F$	0.05	0.45	0.05	64	71	25° (0.8)	5.38 (d, CH_2) $J_{HF} = 14$ Hz	18.5 (s, COF) 107.8 (b, $FCNO_2$)
V, $-CH_3$	0.05	0.65	0.05	64	70	61° (0.7)	2.25 (s, CH_3) 5.07 (s, CH_2)	19.3 (s, COF)
VII, $-CH_2OCOF$	0.10	0.94	0.20	84	91	75–80° (0.2)	5.20 (s, CH_2)	18.7 (s, COF)

[a] Elemental analyses (C, H, N) in agreement with theoretical values were obtained and submitted for review. [b] All reactions were run at ambient temperature. [c] Ir recorded neat between NaCl plates, reported in cm^{-1}; abbreviations are: s, strong; b, broad; 1825–1850 (s, COF), 1600 (s, $C-NO_2$), 1250–1300 (sb, C—F) for all compounds. [d] ^1H chemical shifts reported in δ values relative to tetramethylsilane; ^{19}F chemical shifts reported relative to fluorotrichloromethane in φ^* units (2); abbreviations are: s, singlet; d, doublet; b, broad.

Table II. Preparation of *Gem*-Dinitroethyl Trifluoromethyl Ethers, $RC(NO_2)_2CH_2OCF_3$[a]

Compound,	Moles			Time,	Temp,	Yield,	Physical Constants		
R =	Fluoroformate	SF_4	HF	hr	°C	%	BP (mm)	n D (°C)	ρ (°C)
II, $-NO_2$	0.044	0.37	0.15	48	85	45	65 (15)	1.4875 (24)	1.65 (25)
IV, $-F$	0.01	0.09	0.22	48	85	63	51 (35)	1.3525 (23)	1.69 (23)
VI, $-CH_3$	0.01	0.09	0.55	48	85	73	25 (0.4)	1.3808 (23)	1.48 (23)
VIII, $-CH_2OCF_3$	0.04	0.38	1.10	63	80	72	28 (1.0)	...	...

[a] Elemental analyses (C, H, N) in agreement with theoretical values were obtained and submitted for review.

Table III. Spectral Properties of *Gem*-Dinitroethyl Trifluoromethyl Ethers, $RC(NO_2)_2CH_2OCF_3$

Compound,	Ir bands,[a]	Nmr[b]	
R =	cm^{-1}	δ	φ^*
II, $-NO_2$	3900 (w, CH) 1610 (s, CNO_2) 1175, 1200 (bs, OCF_3)	4.52 (s, CH_2)	62.8 (s, OCF_3)
IV, $-F$	3000 (w, CH) 1600 (s, CNO_2) 1175 (bs, OCF_3, 1350 CF)	5.01 (d, CH_2, $J = 15$ Hz)	108.2 (bs, $FCNO_2$) 61.2 (d, OCF_3, $J_{FF} = 3$ Hz)
VI, $-CH_3$	3000 (w, CH) 1600 (s, CNO_2) 1175, 1350 (bs, OCF_3)	2.23 (s, CH_3) 4.75 (s, CH_2)	63.0 (s, CF_3)
VIII, $-CH_2OCF_3$	3000 (w, CH) 1600 (s, CNO_2) 1150–1300 (bs, CF)	4.90 (s, CH_2O)	62.2 (s, OCF_3)

[a] Ir recorded neat between NaCl plates are recorded in cm^{-1}. Abbreviations are: s, strong; b, broad; w, weak. [b] Nmr ^1H chemical shifts reported in δ values relative to tetramethylsilane. ^{19}F chemical shifts reported relative to fluorotrichloromethane in φ^* units (2). Abbreviations are: s, singlet; d, doublet; b, broad.

perature for 60–70 hr. Autogenous pressure was usually about 800–1100 psig. The autoclave was cooled to −78°C, and the toxic gases were vented through 10% potassium hydroxide solution as the autoclave warmed to ambient temperature. The contents of the vessel were washed with four 20-ml portions of methylene chloride. The sodium fluoride was removed by filtration, methylene chloride was removed at water aspirator pressure, and the fluoroformate was isolated and distilled under reduced pressure.

General preparation of trifluoromethyl ethers. Sulfur tetrafluoride and anhydrous hydrogen fluoride were condensed into a cold (−78°C) 300-ml autoclave containing the fluoroformate. The autoclave was sealed and heated at 85–90°C in a rocking assembly for 48–72 hr. Autogenous pressure was usually 400–700 psig. The autoclave was cooled to −78°C, and the noxious gases were vented through a 10% potassium hydroxide solution as the vessel warmed to ambient temperature. The product was dissolved in 50 ml of methylene chloride and poured into a flask containing 10–30 ml of methylene choride and 5 grams of a 1:1 mixture of potassium fluoride:magnesium sulfate to remove the last traces of hydrogen fluoride. The solids were removed by filtration, the solvent was removed at water aspirator pressure, and the products were purified by distillation under reduced pressure.

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