

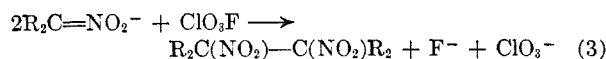
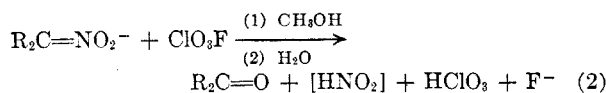
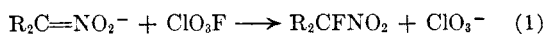
[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, THE OHIO STATE UNIVERSITY]

Reactions of Perchloryl Fluoride and Salts of Mononitro Compounds^{1a}HAROLD SHECHTER AND ELBERT B. ROBERSON, JR.^{1b}

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A preparative method has been developed by which sodium salts of secondary nitroalkanes and nitrocycloalkanes are converted by perchloryl fluoride to the corresponding fluoronitro compounds in moderate conversions (36–42%); competitive processes yield ketones (32–55%) and the *vicinal* dinitro compounds (1–7%) derived from oxidative dimerization of the parent mononitronate ions. Reactions of salts of primary nitro compounds with perchloryl fluoride under various conditions give aldehydes as principal products along with *vicinal* oxidative dimers; the method is inadequate for preparing 1-fluoro-1-nitroalkanes and 1,1-difluoro-1-nitroalkanes efficiently.

An investigation has been made of the reactions of perchloryl fluoride and sodium salts of mononitro compounds as a method for preparing fluoronitro derivatives.² It has been found that sodium salts of secondary nitro compounds react with perchloryl fluoride in methanol at 0° to 10° to give the desired fluoronitro compounds (Equation 1) in moderate conversions (36–42%); competitive processes result in the formation of ketones (32–55%, Equation 2) and of *vicinal* dinitro compounds (1–7%, Equation 3) derived by oxidative-coupling of the parent mononitronate ions. Thus reaction of sodium 2-propanenitronate and excess perchloryl fluoride in methanol gave 2-fluoro-2-nitro-



(1) (a) Abstracted from a portion of the Ph.D. Dissertation of E. B. Roberson, Jr., The Ohio State University, 1959. Financial support of this research was provided by the Office of Naval Research. (b) Present address: E. I. du Pont de Nemours and Co., Inc., Seaford, Del.

(2) (a) C. E. Inman, R. E. Oesterling, and E. A. Tyczkowski, *J. Am. Chem. Soc.*, **80**, 6533 (1958) have found that base-catalyzed reactions of perchloryl fluoride with active methylene compounds such as diethyl malonate, ethyl acetoacetate, 2,4-pentanedione, diethyl ethylmalonate, and diethyl phenylmalonate yield fluorinated derivatives. In general, the reaction replaces all hydrogens of an active methylene group. Similarly reaction of cholestan-3-one pyrrolidyl enamine with perchloryl fluoride and hydrolysis of the product affords 2 α -fluorocholestan-3-one, R. B. Gabbard and E. V. Jensen, *J. Org. Chem.*, **23**, 1406 (1958). (b) J. P. Freeman and C. O. Parker, Abstracts of 135th Meeting of the American Chemical Society, April 5–10, 1959, p. 104-O, report that (1) salts of oximinomalonic esters are oxidized and fluorinated by perchloryl fluoride to produce fluoronitromalonic esters, (2) the sodium salt of α -benzil monoxime is converted by perchloryl fluoride to benzonitrile, benzil monoxime benzoate, and α -fluoro- α -nitro- α -phenylacetophenone, and (3) benzophenone and acetophenone oximes react with perchloryl fluoride to yield the parent ketones and nitrate ions; an unidentified nitro compound was also produced in the reaction of acetophenone oxime.

propane (36% conversion), acetone (54%), and 2,3-dimethyl-2,3-dinitrobutane (6%). Similarly, sodium 2-butanenitronate yielded 2-fluoro-2-nitrobutane (38%), 2-butanone (about 45%), and 3,4-dimethyl-3,4-dinitrohexane³ (7%); sodium cyclohexanenitronate gave 1-fluoro-1-nitrocyclohexane (42%), cyclohexanone (53%), and 1,1'-dinitrobicyclohexyl (1.5%).⁴

A study was made of reaction of sodium 2-propanenitronate with perchloryl fluoride⁵ in methanol at different temperatures and with various ratios of base to nitro compound in an attempt to improve the selectivity in conversion to 2-fluoro-2-nitropropane. In general, formation of products was insensitive to the experimental conditions (–38–10°, mole ratio of base to 2-nitropropane from 1:1 to 2:1) in that 2-fluoro-2-nitropropane, acetone, and 2-3-dimethyl-2,3-dinitrobutane were obtained in 32–36%, 33–54%, and 5–7% conversions, respectively; the principal reaction of perchloryl fluoride and the nitronate anion is oxidation to acetone. Similar results were obtained in reaction of excess perchloryl fluoride at 0–10° with anhydrous sodium 2-propanenitronate suspended in ethyl ether.

Reactions of perchloryl fluoride and sodium salts of primary nitro compounds in methanol (0–10°) or dimethyl formamide (15–20°) gave aldehydes as principal products. Thus sodium 1-propanenitronate with excess perchloryl fluoride in methanol yielded propionaldehyde (64%), 3,4-dinitrohexanes (about 0.5%), 1-nitropropane (38% recovery) and a mixture of 1-fluoro-1-nitropropane and 1,1-difluoro-1-nitropropane in poor yields (3–5%). The results obtained in reactions of sodium ethane-

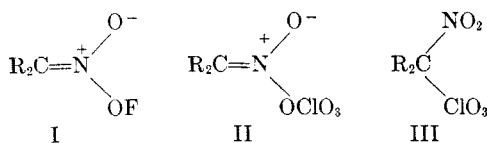
(3) This product may exist in *meso* and *dl*-modifications; the stereochemistry of the product has not been determined.

(4) Fluoronitro compounds derived from secondary mononitronates are quite stable to nucleophilic reagents as compared to the corresponding chloro, bromo, or iodo derivatives. Treatment of the fluoronitro compounds with aqueous 25% sodium hydroxide, methanolic sodium methoxide, or saturated sodium bisulfite gave no reaction. The fluorinated derivatives were thus conveniently separated from starting material and oxidation products by extraction with 10–25% aqueous base and saturated sodium bisulfite.

(5) 2-Nitropropane and perchloryl fluoride do not react in methanol unless a base is present.

nitronate with perchloryl fluoride under various conditions were similar to those for sodium 1-propanenitronate. Reaction of primary mononitronates with perchloryl fluoride is an unsatisfactory preparative method for monofluoronitro or difluoronitro compounds because of the poor yields and the difficulties in effecting their separation by physical or chemical methods.

The mechanisms of conversion of a nitronate salt to fluoronitro compound, aldehyde or ketone, and *vicinal* coupling product are as yet unknown. It is presumed that the fluoronitro compounds are derived by nucleophilic attack of the nitronate ion on perchloryl fluoride with displacement of chlorate ion.⁶ Aldehydes or ketones and the *vicinal* dinitro compounds may be formed from intermediates such as I-III by thermal decomposition, hydrolysis, or by displacement by the nitronate anion, respectively.⁷



EXPERIMENTAL

Reaction of perchloryl fluoride and sodium 2-propanenitronate. 2-Nitropropane (66.8 g., 0.75 mol.) was added dropwise to a stirred solution of sodium methoxide (40.5 g., 0.75 mol.) in anhydrous methanol (500 ml.) at 0–5° in a glass flask equipped with a thermometer, gas inlet tube, Teflon paddle stirrer, and a Dry Ice condenser equipped with a calcium chloride drying tube. The mixture was stirred for 2 hr. at these temperatures and then 2 additional hr. at 15–20°. Perchloryl fluoride was added to the vigorously stirred reaction mixture at 0° at a rate of 1 mol. in 45 min. via a flowmeter containing Fluorolube and connected by Tygon tubing. (Care was taken that the gas inlet tube did not project below the surface of the reaction mixture to prevent possible suckback into the perchloryl fluoride cylinder; gaseous perchloryl fluoride dissolves very readily in the solvents under these conditions.)⁹ The reactions are

(6) Sodium chlorate is isolated in 50–70% yields upon filtering the methanolic reaction mixtures at –20°.

(7) (a) An alternative mechanism for formation of carbonyl and of *vicinal* dinitro compounds involves oxidation of a nitronate ion to the corresponding radical; the radical may lose nitric oxide to yield the aldehyde or ketone or undergo dimerization; see H. Shechter and R. B. Kaplan, *J. Am. Chem. Soc.*, **75**, 3980 (1953). (b) Reaction of 2-fluoro-2-nitropropane and sodium 2-propanenitronate to give acetone or 2,3-dimethyl-2,3-dinitrobutane does not take place under the conditions of the fluorination experiments.

(8) The mixtures obtained from each nitro compound were heterogeneous, but addition of sufficient methanol to effect complete solution of the sodium salts did not increase the yield of fluoronitro compounds. In addition to increasing the amount of the relatively expensive perchloryl fluoride required, excess methanol increased the difficulty of extracting the products from the reaction mixture. Ethanol is a satisfactory solvent for this reaction, but it is more difficult to separate from the products. Water, water-ethylene glycol, and ethylene glycol were unsatisfactory solvents in that they led to poor efficiencies in fluorination.

very exothermic and, occasionally, it was necessary to interrupt the addition to prevent the temperature of the mixture from exceeding 10° even in an efficient ice-salt slurry. Perchloryl fluoride is sufficiently soluble in methanol at 0–10° so that reflux in the Dry Ice condenser did not occur until approximately 0.75 mol. of perchloryl fluoride had been added. In addition to judging the extent of reaction by the volume of perchloryl fluoride added, a sharp temperature drop occurred when the excess perchloryl fluoride began to reflux. Additional perchloryl fluoride was then added so that completion of reaction was assured and the mixture then stirred for 1 hr. at 0°. The ice bath and Dry Ice condenser were then removed, and the mixture was stirred until its temperature reached 20°. During addition of perchloryl fluoride the mixture turns blue; the color is presumed to be due to 2-nitro-2-nitrosopropane resulting from reaction of nitrous acid with 2-propanenitronic acid. The mixture was acidic upon completion of the experiment.

The reaction mixture was poured into five times its volume of ice water, and the resultant solution extracted thoroughly with ether. The combined ether extracts were washed with water until the volume of ether extract remained constant. This procedure removed the methanol from the ether solution and simplified isolation of the 2-fluoro-2-nitropropane. The ether solution was extracted with saturated brine, filtered through sodium sulfate and magnesium sulfate, respectively, and then rectified slowly in a glass-helix column (25 cm.). The fractionation was ineffective in separating the 2-fluoro-2-nitropropane from 2-nitropropane. An ether solution of the crude product was stirred with sodium hydroxide (20 g., 0.5 mol.) in water (150 ml., 13%) for two days, washed with water and saturated brine, and then dried over magnesium sulfate. Fractionation of the ether and distillation (twice) of the product yielded 2-fluoro-2-nitropropane (25.6 g., 32% conversion), colorless liquid, b.p. 111–111.2° (uncorr.), n_D^{20} 1.3739, d_4^{20} 1.083; infrared absorption for a nitro group (6.37 μ , asymmetrical stretching; 7.37 μ , symmetrical stretching).

Anal. Calcd. for $\text{C}_3\text{H}_6\text{NO}_2\text{F}$: C, 33.65; H, 5.61; N, 13.08. Found: C, 33.99; H, 5.61; N, 12.87.

Recrystallization of the distillation residue (7.1 g., 10.8% crude conversion) from ethanol-water gave 2,3-dimethyl-2,3-dinitrobutane (4.9 g., 7.4% conversion), white crystals, m.p. 205°, lit.¹⁰ m.p. 209°, no depression by an authentic sample.

The yield of acetone was determined from a separate experiment in which perchloryl fluoride was added to 2-nitropropane (4.45 g., 0.05 mol.) and sodium methoxide (2.70 g., 0.05 mol.) in methanol (50 ml.) at 0°. The mixture was diluted to 100 ml.; addition of a 5.0-ml. aliquot to an acid solution of 2,4-dinitrophenylhydrazine (0.6 g., 0.003 mol.) gave acetone 2,4-dinitrophenylhydrazone (0.1406 g.), m.p. 125°, lit.¹¹ m.p. 126°. The correction in weight due to solubility of the derivative as derived from experiments with acetone as a blank was 0.052 g. The total weight of acetone 2,4-dinitrophenylhydrazone (0.1926 g.; theory 0.595 g.) corresponds to a 22% conversion.

(9) Perchloryl fluoride is a stable compound quite safe to handle. It is however a powerful oxidizing agent and all mixtures with oxidizable substances should be considered potentially dangerous. No difficulties were encountered in handling perchloryl fluoride under the conditions of the present experiments. The details of handling and safety of perchloryl fluoride have been fully described; Booklet DC-1819, "Perchloryl Fluoride," Commercial Development Dept., Pennsalt Chemicals Corp., 3 Penn Center, Philadelphia 2, Penn.

(10) L. W. Seigle and H. B. Hass, *J. Org. Chem.*, **5**, 100 (1940).

(11) R. L. Shriner and R. C. Fuson, "Identification of Organic Compounds," 3rd ed., John Wiley & Sons, Inc., New York, N. Y., 1948, p. 262.

In a subsequent experiment with excess perchloryl fluoride, 2-nitropropane (0.75 mol.) and sodium methoxide (1.5 mol.) at 0 to 10°, 2-fluoro-2-nitropropane, acetone, and 2,3-dimethyl-2,3-dinitrobutane were obtained in 36%, 54%, and 6% conversions, respectively. Reaction of 2-nitropropane (1.0 mol.), sodium methoxide (1.5 mol.) and excess perchloryl fluoride at -35 to -38° in methanol (1500 ml.) gave similarly 2-fluoro-2-nitropropane, acetone, and 2,3-dimethyl-2,3-dinitrobutane in 32%, 51%, and 5.4% conversions, respectively.

Reaction of perchloryl fluoride and sodium 2-butanenitronate. Reaction of 2-nitrobutane (51.6 g., 0.5 mol.), sodium methoxide (40.5 g., 0.75 mol.), and excess perchloryl fluoride in methanol (900 ml.) was effected at 0-5°. The initial ether extract was concentrated, stirred overnight with saturated aqueous sodium bisulfite, separated, and stirred for 6 hr. with 20% sodium hydroxide. The bisulfite and sodium hydroxide extractions were repeated to remove impurities indicated by infrared examination. Fractionation of the ether and distillation of the residue gave colorless 2-fluoro-2-nitrobutane (23.4 g., 38% conversion), b.p. 74° (115 mm.), n_D^{20} 1.3888; infrared absorption for a nitro group (6.36 and 7.33 μ).

Anal. Calcd. for $C_4H_9NO_2F$: C, 39.67; H, 6.66; N, 11.57; F, 15.69. Found: C, 39.43; H, 6.64; N, 11.50; F, 15.58.

The distillation residue upon recrystallization from methanol gave 3,4-dimethyl-3,4-dinitrohexane³ (3.54 g., 7% conversion), m.p. 77-78°, lit.¹² m.p. 79-80°; no depression by an authentic sample. An additional experiment with perchloryl fluoride and sodium 2-butanenitronate allowed isolation of 2-butanone as its 2,4-dinitrophenylhydrazone, m.p. 116°, lit.¹¹ 117°, in about 45% conversion.

Reaction of perchloryl fluoride and sodium cyclohexanenitronate. Reaction of nitrocyclohexane (129.2 g., 1.0 mol.), sodium methoxide (108 g., 1.0 mol.), and excess perchloryl fluoride was conducted at 0 to 10°. Isolation of the products (preferred procedure) after the initial ether solution was exhaustively extracted with saturated aqueous sodium bisulfite (twice, overnight) and 20% sodium hydroxide gave colorless 1-fluoro-1-nitrocyclohexane (62.1 g., 42% conversion), b.p. 94° (34 mm.), n_D^{20} 1.4416, n_4^{20} 1.153; infrared absorption for a nitro group (6.39 and 7.37 μ).

Anal. Calcd. for $C_6H_{10}NO_2F$: C, 48.97; H, 6.85; N, 9.52. Found: C, 48.88; H, 6.94; N, 9.71.

The distillation residue (3.4 g., 2.6% crude conversion) yielded 1,1'-dinitrobicyclohexyl (1.84 g., 1.4%) upon recrystallization from ethanol, m.p. 215-219°, lit.¹³ m.p. 217°, no depression by an authentic sample. The conversion to cyclohexanone was determined by separate experiment; the corrected crude conversion to cyclohexanone 2,4-dinitrophenylhydrazone, m.p. 159-161°, lit.¹¹ m.p. 161°, was 53%.

(12) I. Bevad and A. Pirinsky, *Ber.*, **39**, 1231 (1906).

Reaction of perchloryl fluoride and sodium 1-propanenitronate. Reaction of 1-nitropropane (133.6 g., 1.5 mol.), sodium methoxide (162 g., 3.0 mol.), and excess perchloryl fluoride in methanol (1.5 l.) was effected at 0-10°. The red, slightly acid mixture was allowed to warm to room temperature, poured into water, and extracted with ether. The ether extract was washed with water, dried with brine, sodium sulfate, and magnesium sulfate, respectively, and rectified to give, after removal of ether: (1) impure propionaldehyde dimethyl acetal (23 g.), b.p. 84.5-89.2°, (2) a mixture of fluorinated 1-nitropropanes and 1-nitropropane (6.6 g.), b.p. 77-78.5° (190 mm.), n_D^{20} 1.3926-1.3991, (3) crude 1-nitropropane (45.6 g., 34% recovery), b.p. 69-72° (100 mm.), n_D^{20} 1.3992-1.4028, lit.¹⁴ n_D^{20} 1.4013, similar infrared absorption, and (4) residue (3.4 g.).¹⁵

Fraction 1 in ether was stirred overnight with aqueous 10% sodium hydroxide, separated, dried, and rectified to yield propionaldehyde dimethyl acetal (20.0 g., 13% conversion), b.p. 87°, n_D^{20} 1.3798, d_4^{20} 0.8505, lit.¹⁶ b.p. 89°, n_D^{21} 1.3799.¹⁶

Anal. Calcd. for $C_5H_{12}O_2$: C, 57.66; H, 11.61. Found: C, 57.68; H, 11.77.

Its identity was confirmed by hydrolysis to propionaldehyde 2,4-dinitrophenylhydrazone, m.p. 153-154°, lit.¹⁷ m.p. 154°. Fraction 2 (6.6 g.) in ether was extracted with excess 5% sodium hydroxide for 2 hr. Distillation of the ether solution gave only trace amounts of fluorinated nitropropanes.¹⁸ Acidification of the alkaline extract at 0° with hydrochloric acid gave additional 1-nitropropane (about 3.0 g.), n_D^{20} 1.4014-1.4018; the apparent instability of 1-fluoro-1-nitropropane in alkaline aqueous media was indicated by the fact that the acidified aqueous extract gave very strong tests for fluoride ion.

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(13) S. S. Nametkin, *J. Russ. Phys. Chem. Soc.*, **42**, 586 (1910); *Chem. Zentr.*, **81**, II, 1376 (1910).

(14) A. I. Vogel, *J. Chem. Soc.*, 1833 (1948).

(15) In an experiment which simulated the one described propionaldehyde was formed in at least 40% conversion and 64% yield.

(16) A. Kirmann, *Ann. chim. (Paris)*, [10], **11**, 262 (1929).

(17) Ref. 11, p. 229.

(18) A reaction was conducted in which perchloryl fluoride (1.2 mol.) was added to a slurry of sodium 1-propanenitronate (1.5 mol.) in dimethylformamide (250 ml.) at 15°. After 2 hr., sodium methoxide (1.5 mol.) and perchloryl fluoride (excess) were added to the mixture; consecutive addition of the reagents was repeated again. The acidic reaction product was extracted with pentane; concentration and analysis of the pentane extract for fluorine indicated that the maximum conversion of 1-nitropropane to fluorine-containing products was 4%.