Reactions of Hexafluoroacetone with Acetals

Robert A. Braun

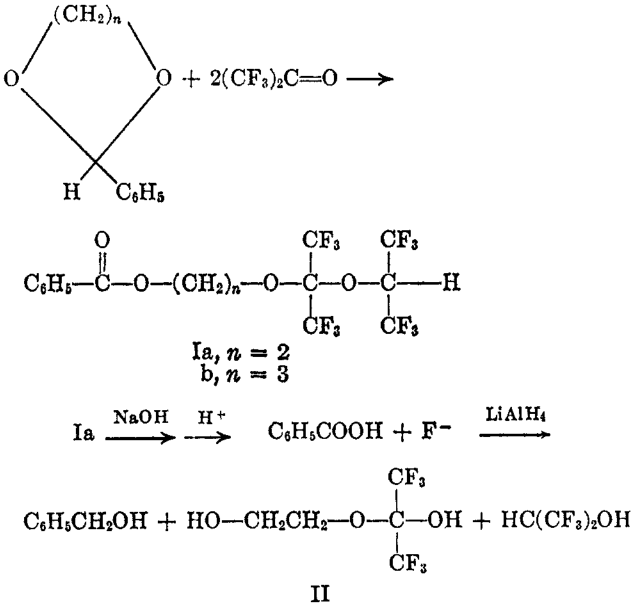
Fabrics and Finishes Department, Experimental Station, E. I. du Pont De Nemours and Company, Wilmington, Delaware 19898

Received January 11, 1966

The reaction of hexafluoroacetone (HFA) with 2-substituted 1,3-dioxolanes gives esters containing two or three units of HFA. A hydride ion transfer mechanism is proposed for these reactions. The free-radical-catalyzed reaction of 1,3-dioxolane with HFA gives the known spiro ether (XII) and the hydrogen-bonded adduct of hexafluoro-2-propanol and 1,3-dioxolane. 2-Methoxytetrahydropyran and HFA give an unsaturated fluoro alcohol (XV) which can also be obtained by the reaction of HFA with dihydropyran. Acrolein dimethyl acetal and 2 moles of HFA give the novel 1,3-dioxane (XXII).

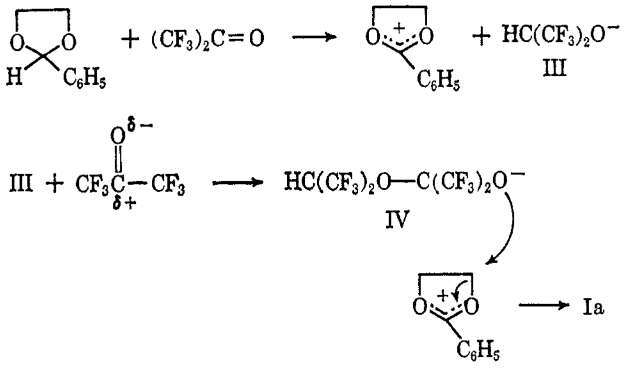
In continuation of our investigation of reactions of the highly reactive electrophilic ketone, hexafluoroacetone (HFA), a variety of new reactions of acetals has been found.[1] There has been no prior work on the reaction of perhalo ketones with acetals.

Reaction of HFA with 2-Phenyl-1,3-dioxolane and 2-Phenyl-1,3-dioxane.—2-Phenyl-1,3-dioxolane reacts with 2 moles of HFA at 150° to give a colorless oil (Ia) in 89% yield. The reaction does not require a catalyst or solvent and the yield of product is not altered by the addition of inhibitors such as hydroquinone or phenothiazine, or by radical sources such as *t*-butyl peroxide or azobisisobutyronitrile. The structure of Ia was determined by fluorine and proton nmr, infrared, and mass spectroscopy in conjunction with elemental analysis and degradation experiments. Saponification of Ia gave benzoic acid and fluoride ion owing to the base sensitivity of the O–C(CF_3)$_2$H group. Lithium aluminium hydride reduction gave benzyl alcohol, hexafluoroisopropyl alcohol, and a glycol tentatively assigned structure II. The structure of the products suggests a hydride ion transfer mechanism for these reactions. The initially formed anion (III), owing to steric effects, reacts with only 1 mole of HFA. The new anion (IV) then effects a nucleophilic displacement on the dioxolanium ion at the 4 position, with formation of the benzoate carbonyl group.



Ia, *n* = 2
b, *n* = 3

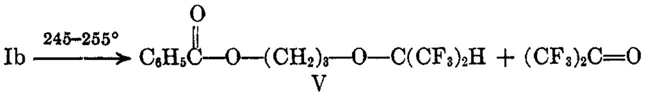
II



III

IV

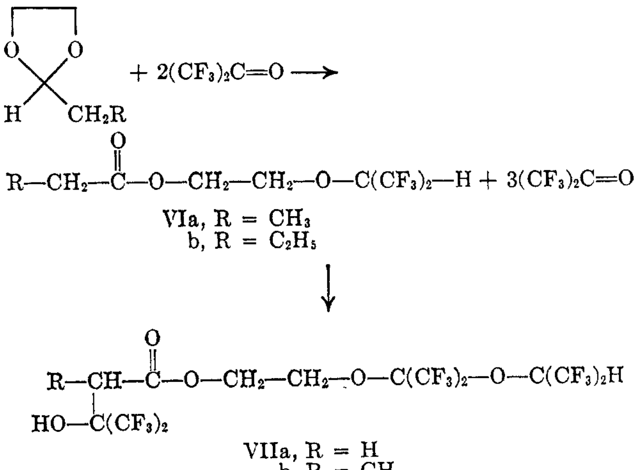
The ester (Ib) from 2-phenyl-1,3-dioxane and HFA lost 1 mole of hexafluoroacetone slowly during heating at 245–255° to give V, which was thermally stable at 250°.



$$\mathrm{Ib} \xrightarrow{245-255^\circ} \mathrm{C_6H_5\overset{\overset{O}{\|}}{C}-O-(CH_2)_3-O-C(CF_3)_2H + (CF_3)_2C{=}O}$$

V

Reaction of HFA with 2-Alkyl-1,3-dioxolanes.—The 2-alkyl-1,3-dioxolanes also react readily with HFA. With 2 moles of HFA a mixture of products was obtained but with 3 moles of HFA a single product was obtained in high yield. The mixed products can be separated easily by distillation to give a low-boiling ester (VIa,b) and a high-boiling hydroxy ester (VIIa–c). The hydroxy esters are the only products from reactions using 3 moles of HFA. The VIa,b products are analogous to the products from 2-phenyl cyclic acetals and III is the result of attack of another mole of HFA



VIa, R = CH_3
b, R = C_2H_5

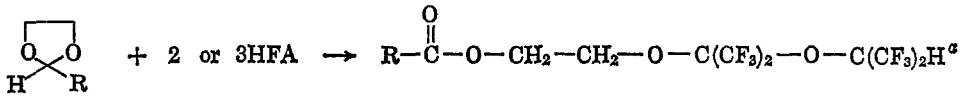
VIIa, R = H
b, R = CH_3
c, R = C_2H_5

---

[1] (a) R. A. Braun, *J. Am. Chem. Soc.*, **87**, 5516 (1965); (b) *J. Org. Chem.*, **31**, 1147 (1966).

TABLE I

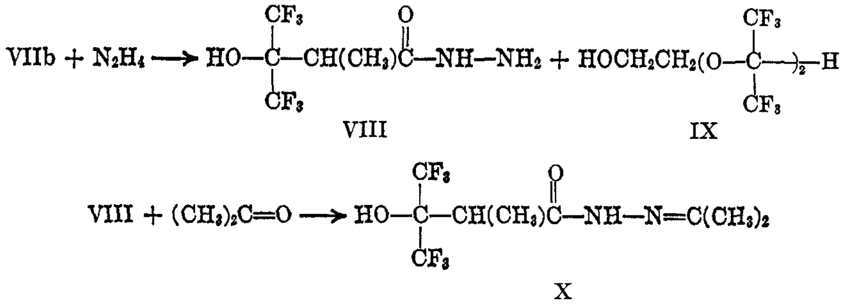
PHYSICAL PROPERTIES OF REACTION PRODUCTS



Compd	R	Bp, °C (mm)	$n^{25}{}_D$	Yield, %	Formula	Carbon, % Calcd	Carbon, % Found	Hydrogen, % Calcd	Hydrogen, % Found	Fluorine, % Calcd	Fluorine, % Found
Ia	C_6H_5	68 (0.15)	1.3990	89.0	$C_5H_{10}F_{12}O_4$[b]	37.36	37.64	2.09	1.90	47.28	47.21
VIIa	$CH_2C(CF_3)_2OH$	103 (1.2)	1.3302	79.4	$C_{13}H_8F_{18}O_5$	26.64	26.94	1.38	1.50	58.34	58.31
VIa	C_2H_5	77 (14.0)	1.3476	5.5	$C_{11}H_{10}F_{12}O_4$	35.83	35.65	3.76	4.03	42.51	42.32
VIIb	$CH(CH_3)C(CF_3)_2OH$	110 (2.5)	1.3352	80.2	$C_{14}H_{10}F_{18}O_5$	28.02	28.09	1.68	1.68	56.97	56.89
VIb	C_3H_7(n)	90–91 (4.3)	1.3415	25.8	$C_{12}H_{12}F_{12}O_4$	32.16	32.46	2.70	2.59	50.86	50.86
VIc	$CH(C_2H_5)C(CF_3)_2OH$	110 (1.4)	1.3408	59.0	$C_{13}H_{12}F_{18}O_5$	29.33	29.65	1.97	1.89	55.68	55.63

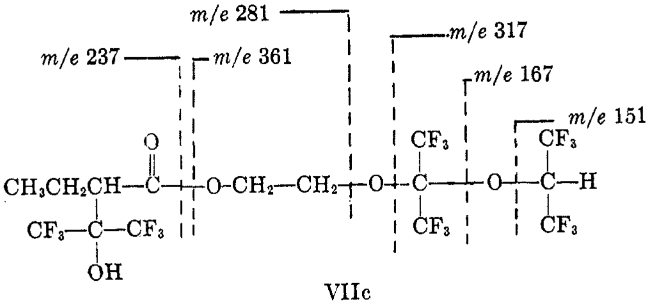
[a] All reactions were run in a stainless steel bomb at 150° for 8 hr at autogenous pressure. [b] Mol wt: calcd, 482; found (cryoscopic in benzene), 480.

SCHEME I



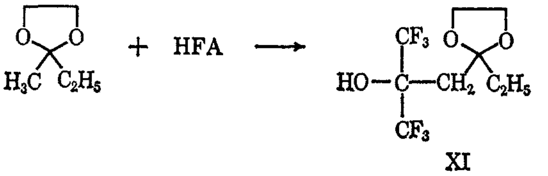
at the activated CH bond adjacent to the carbonyl group. The physical properties of these compounds are summarized in Table I.

The mass spectra of the adducts from 2-substituted 1,3-dioxolanes and HFA provide additional support for the proposed structures. This is illustrated by the fragmentation observed for the 3:1 adduct of HFA and 2-propyl-1,3-dioxolane (VIIc), *m/e* 586 (parent ion minus [C–O]+). Similar fragmentation patterns were obtained for VIa and VIIa. The reaction of VIIb with hydrazine gives the crystalline hydrazide (VIII) in quantitative yield along with the ketal alcohol (IX). The hydrazide (VIII) was characterized by elemental analysis as well as its rapid reaction with acetone to give X (see Scheme I).



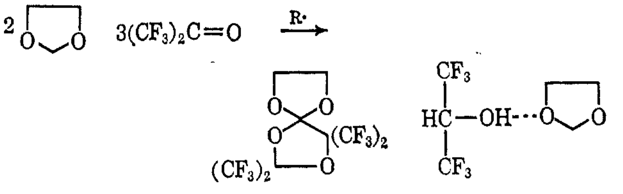
VIIc

The disubstituted dioxolane, 2-methyl-2-ethyl-1,3-dioxolane, also reacts readily with HFA at 150° to give 72.4% of the fluoro alcohol (XI) resulting from electrophilic attack of HFA at the activated methyl group.



XI

Reaction of HFA with 1,3-Dioxolane.—1,3-Dioxolane did not react with HFA at 150° but with a catalytic amount of *t*-butyl hydroperoxide there was rapid reaction with HFA to give two products, XII and the hydrogen-bonded adduct XIII. Compound XII was reported previously.[1a] The hydrogen-bonded adduct XIII was characterized by its proton nmr and infrared spectra as well as elemental analysis and independent synthesis from hexafluoropropyl alcohol and 1,3-dioxolane. The hydrogen-bonding tendency of hexafluoropropyl alcohol has been noted previously.[2]



XII XIII

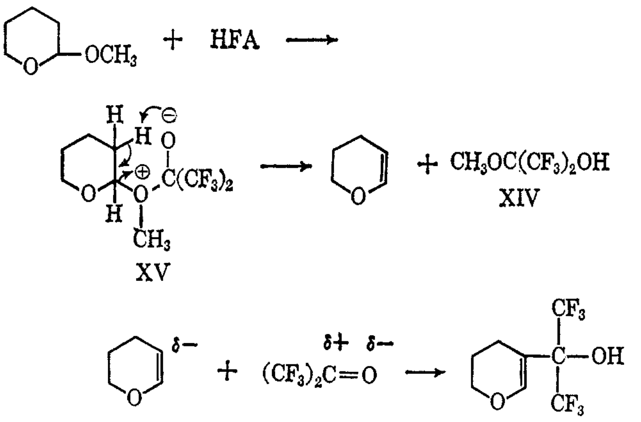
The mechanism of this free-radical-induced oxidation–reduction reaction is not yet known.

Reaction of HFA with 2-Methoxytetrahydropyran.—The acetal, 2-methoxytetrahydropyran, reacts with HFA without catalyst or solvent to give the hemiketals XIV and XV. The initial step in this reaction is most likely the coordination of a molecule of HFA with the methoxy oxygen followed by elimination of XIV and the formation of dihydropyran which then reacts with another mole of HFA to give the fluoro alcohol XV. In support of this reaction sequence, it was found that the reaction of dihydropyran with HFA gave XV as the only product. This may be a direct attack of the electrophilic HFA at the electron-rich site of dihydropyran; however, the possibility of a stepwise reaction as noted with other vinyl ethers cannot be excluded.[3]

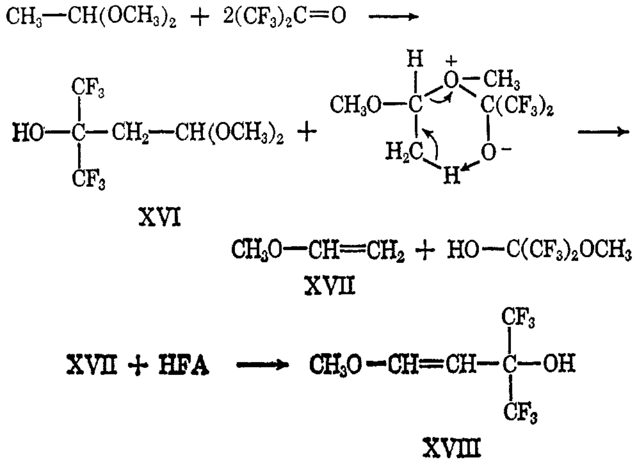
---

(2) W. J. Middleton and R. V. Lindsey, Jr., *J. Am. Chem. Soc.*, **86**, 4948 (1964).

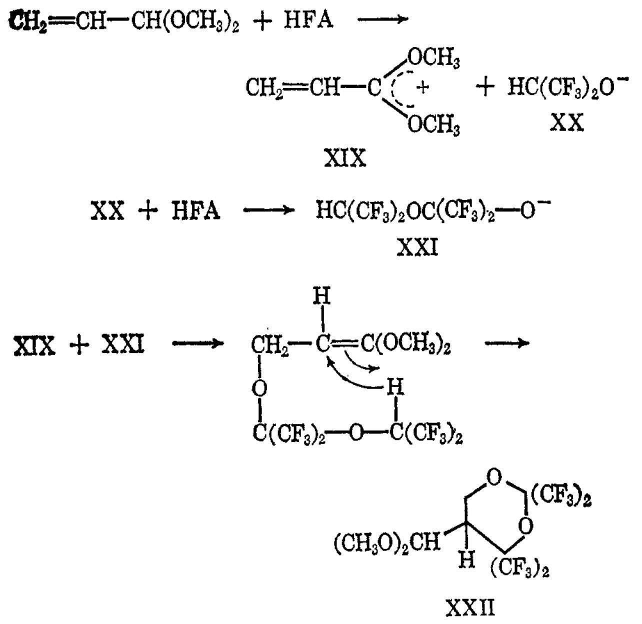
(3) H. R. Davis, 140th National Meeting of the American Chemical Society, Chicago, Ill., Sept 1961; U. S. Patent 3,164,610 (1961).



Reaction of HFA with Aliphatic Acetals.—The reaction of HFA with acetaldehyde dimethyl acetal at 140° gave a mixture of products which could be separated by gas chromatography. The products XVI and XVIII result from a competition between the attack of HFA at the activated methyl group to give XVI and the coordination of HFA with the ether oxygen of the acetal. The remaining steps are similar to those described for the reaction of HFA with 2-methoxytetrahydropyran.



HFA reacts with acrolein dimethyl acetal to give principally a 2:1 adduct (XXII). The 1,3-dioxolane structure has been assigned on the basis of elemental analysis and infrared, proton nmr and mass spectral analysis. The initial step in this reaction may also be a hydride ion abstraction with the formation of a carbonium ion.



Experimental Section[4]

Preparation of Cyclic Acetals.—The 2-alkyl-1,3-dioxolane and 2-phenyl-1,3-dioxolane and dioxane were prepared by the method of Rieche[5] and were fractionated on a spinning-band column immediately before use.

4,4,6-Tris(trifluoromethyl)-7,7,7-trifluoro-3,5-dioxaheptyl Benzoate (Ia).—Hexafluoroacetone (70.0 g, 0.42 mole)[6] was added to 2-phenyl-1,3-dioxolane (30.0 g, 0.2 mole) and benzene (50.0 g) in a 200-ml stainless steel bomb and was heated at autogenous pressure for 8 hr at 175°. The solvent was removed by stripping at 25° (10 mm), and the residue was fractionated on a spinning-band column to give a colorless liquid. See Table I for physical constants and Table II for nmr of this and related

TABLE II

PROTON NMR FOR REACTION PRODUCTS

Compd	Proton or group of protons	τ value	Multiplicity	Integrated peak area
Ia	C_6H_5	2.42 and 3.07	m[a]	5
	$C(CF_3)_2H$	5.02	7	1
	OCH_2C	5.95	2	4
Ib	C_6H_5	1.95 and 2.58	m	5
	$C(CF_3)_2H$	4.53	7	1
	OCH_2C	5.63	5	4
	OCH_2C	7.88	5	2
VIIa	OH	3.75	1	1
	$C(CF_3)_2H$	4.95	7	1
	OCH_2C	5.58	1	4
	$\overset{\text{O}}{\overset{\|}{\text{C}}}\text{—CH}_2\text{C}$	7.04	1	2
VIa	$C(CF_3)_2H$	4.67	7	1
	OCH_2C	5.62	1	4
	$\text{C}\mathit{H}_2\text{CH}_3$ preceded by C: $\text{C}\mathit{CH}_2\text{CH}_3$	7.66	4	2
VIIb	OH	3.85	1	1
	$C(CF_3)_2H$	4.89	7	1
	OCH_2C	5.54	1	4
	CH	6.80	4	1
	$\text{CH}\mathit{CH}_3$	8.52	2	3
VIb	$C(CF_3)_2H$	4.67	7	1
	OCH_2C	5.63	1	4
	$\overset{\text{O}}{\overset{\|}{\text{C}}}\text{CH}_2\text{C}$	7.65	3	2
	$\text{O}\mathit{CH}_2\text{CH}_3$	8.32	6	2
	$\text{CH}_2\mathit{CH}_3$	9.03	3	3
VIIc	OH	4.25	1	1
	$C(CF_3)_2H$	4.92	7	1
	OCH_2C	5.58	1	4
	CH	6.98	3	1
	$\mathit{CH}_2\text{CH}_3$	8.03	4	2
	$\text{CH}_2\mathit{CH}_3$	9.01	3	3

[a] m = multiplet.

---

(4) Melting points and boiling points are uncorrected. Infrared spectra were recorded by a Perkin-Elmer Infracord spectrophotometer. Fluorine nmr spectra were obtained with a Varian Associates high-resolution nmr spectrometer operating at 56.4 Mcps. Spectra were calibrated in terms of higher field displacement in parts per million from the F^{19} resonance of 1,2-difluoro-1,1,2,2-tetrachloroethane used as an external reference. Proton resonance spectra were obtained with a Varian Associates A-60 spectrometer. For the pressure reactions a 500-ml stainless steel bomb was used at autogenous pressure.

(5) A. Rieche, E. Schmitz, and E. Beyer, *Ber.*, **91**, 1935 (1958).

(6) Commercial hexafluoroacetone of 99.5+% purity, obtained from E. I. du Pont de Nemours and Co., was used.

compounds: infrared: 5.79 μ (ester C=O) and no OH or C=C bands. The fluorine nmr showed two equal peaks at +377 and +565 cps. The mass spectrum contains the parent ion (*m/e* 482) and the following major fragments: *m/e* 317, $[C(CF_3)_2OC(CF_3)_2H]^+$; *m/e* 149, $[CH_2CH_2OC(O)C_6H_5]^+$; *m/e* 105, $[C(O)C_6H_5]^+$; *m/e* 69, $[CF_3]^+$.

Reduction of 4,4,6-Tris(trifluoromethyl)-7,7,7-trifluoro-3,5-dioxaheptyl Benzoate (Ia).—To a slurry of 8.0 g (0.21 mole) of lithium aluminum hydride in 100 ml of anhydrous ether was added 24.5 g (0.051 mole) of Ia at 25–30°. After stirring for 2 days, the excess $LiAlH_4$ was neutralized by adding ethyl acetate followed by 10% sulfuric acid. The ether layer was removed and the water layer was extracted twice with ether. The combined ether extracts were dried over $MgSO_4$ and stripped, and the 13.8 g of oil was fractionated to give $(CF_3)_2CHOH$. The infrared and proton nmr spectra and gas chromatographic retention time were identical with those of an authentic sample of hexafluoropropyl alcohol. The fraction with bp 85–89° (760 mm) (1.9 g) is probably $HOCH_2CH_2OC(CF_3)_2OH$: infrared, 2.90 and 3.20 μ (aliphatic OH and fluoro alcohol OH, respectively[2]).

Anal. Calcd for $C_5H_6F_6O$: C, 26.33; H, 2.65; F, 49.98; OH (for two OH groups), 14.9. Found: C, 26.66; H, 3.11; F, 49.80; OH, 15.7.

The infrared spectrum of the residue (1.6 g) was identical with that of benzyl alcohol as was the retention time on gas chromatographic analysis.

5,5,7-Tris(trifluoromethyl)-8,8,8-trifluoro-4,6-dioxaoctyl Benzoate (Ib).—Hexafluoroacetone (250.0 g, 1.5 moles) and 2-phenyl-1,3-dioxane (110.1 g, 0.67 mole) were heated at 150° for 8 hr. The product was fractionated to give 69.3 g of unreacted 2-phenyl-1,3-dioxane and 82.0 g (66.3% based on 2-phenyl-1,3-dioxane consumed) of Ib (bp 120° (3.0 mm), n^{22}_{D} 1.3975.

Anal. Calcd for $C_{16}H_{12}F_{12}O_4$: C, 38.72; H, 2.44; F, 45.94. Found: C, 38.71; H, 2.50; F, 45.57.

5-Trifluoromethyl-6,6,6-trifluoro-4-oxahexyl Benzoate (V).—In a 100-ml flask fitted with a water-cooled condenser leading to an ice-cooled trap followed by a Dry Ice cooled trap, 49.6 g (0.1 mole) of Ib was heated under N_2 for 18 hr at 245–255°. The ice-cooled trap contained 9.6 g (0.058 mole) of hexafluoroacetone characterized by its boiling point (−28°) and infrared spectrum. The residue in the flask (26.2 g) was fractionated to give 18.0 g (54.5%) of V: bp 88–89° (0.5 mm); n^{25}_{D} 1.4268; infrared: 5.88 μ (ester C=O) and no OH or C=C bonds; proton nmr: τ 2.00 and 2.50 (multiplets, five phenyl protons), 5.50 to 6.12 (multiplets, 4 $-C-CH_2-O$ protons overlapping $C-(CF_3)H$ proton), and 7.95 (quintuplet, $CH_2-\mathit{CH}_2-CH_2$).

Anal. Calcd for $C_{13}H_{12}F_6O_3$: C, 47.28; H, 3.66; F, 34.52. Found: C, 47.58; H, 3.71; F, 34.54.

A final residue from the distillation (6.0 g) was not identified.

Reaction of VIIb with Hydrazine.—Hydrazine hydrate (15.0 g, 0.3 mole) was added to a solution of VIIb (60.0 g, 0.1 mole) in 100 ml of benzene. The mixture was refluxed for 3 hr using a water separator. The theoretical amount of water was collected (7.2 ml). The benzene solution was cooled to 0° and the white crystals were collected, washed with hexane, and dried to give 26.8 g (100%) of the hydrazide (VIII): mp 101–102°; infrared: 3.02, 3.12, and 3.22 μ (NH and OH peaks), 5.92 μ (C=O).

Anal. Calcd for $C_6H_6F_6N_2O$: C, 28.36; H, 3.17; F, 44.85; N, 11.02. Found: C, 28.31; H, 3.42; F, 44.60; N, 10.90.

The filtrate was fractionated on a spinning-band column to give 30.0 g (79.4%) of the alcohol IX: bp 164° (760 mm); n^{25}_{D} 1.3195; infrared band at 2.97 μ (OH) and no C=O or C=C bands; nmr: τ 4.63 (septuplet, $O-C(CF_3)_2H$), 5.97 (singlet, -OH), 6.17 (2 H), and 5.83 (2 H) (multiplet, $O-CH_2-CH_2-O$).

Anal. Calcd for $C_8H_6F_{12}O_3$: C, 25.41; H, 1.60; F, 60.29. Found: C, 25.27; H, 1.69; F, 60.24.

Reaction of VIII with Acetone.—Excess acetone (30.0 g) reacted exothermically with 15.0 g (0.059 mole) of the hydrazide VIII. The mixture was heated at 50° for 30 min and cooled, and the white crystals were collected and dried to give 17.4 g (86.2%) of X: mp 179–180°; infrared: 3.10 (OH), 3.28 (NH), and 6.14 μ (overlapping bands) (C=O and C=N).

Anal. Calcd for $C_9H_{12}F_6N_2O_2$: C, 36.74; H, 4.11; F, 38.74; N, 9.52. Found: C, 37.19; H, 4.12; F, 38.47; N, 9.33.

2-Ethyl-2(3,3,3-trifluoro-2-trifluoromethyl-2-hydroxypropyl)-1,3-dioxolane (XI).—2-Methyl-2-ethyl-1,3-dioxolane (50.0 g, 0.43 mole) and excess hexafluoroacetone (143.0 g, 0.86 mole) were heated in a bomb at 150° for 6 hr. The crude product was fractionated on a spinning-band column to give 87.5 g (72.4%) of XI: bp 62–63° (2 mm), 191° (760 mm); n^{25}_{D} 1.3721; infrared: 2.92 μ (OH) and no C=O or C=C bands; proton nmr: τ 4.28 (singlet) (OH), 5.98 ($O-CH_2CH_2O-$), 7.72 (singlet, $C-CH_2-C-(CF_3)-O-$), 8.21 (quadruplet, $-C-\mathit{CH}_2-CH_3$), and 9.07 (triplet, $CH_2\mathit{CH}_3$).

Anal. Calcd for $C_9H_{12}F_6O_3$: C, 38.31; H, 4.29; F, 40.39. Found: C, 38.02; H, 4.21; F, 40.65.

Nine grams of a high-boiling product [bp 105° (2.0 mm)] was suspected to be an adduct containing 2 moles of HFA. This material has not been completely characterized.

Reaction of 1,3-Dioxolane with HFA.—HFA did not react with 1,3-dioxolane in the absence of solvent and initiator at 150° and 175°. 1,3-Dioxolane (35.2 g, 0.4 mole), HFA (100.0 g, 0.8 mole), and 1.0 g of *t*-butyl peroxide were heated at 135° for 8 hr in a bomb. The 130 g of crude product was fractionated to give 39.3 g of the hydrogen-bonded adduct of hexafluoropropyl alcohol and 1,3-dioxolane (XIII), bp 91° (760 mm), n^{25}_{D} 1.3208. The boiling point, index of refraction, and infrared and proton nmr of XIII were identical with those of the adduct obtained by mixing equimolar quantities of pure hexafluoropropyl alcohol and 1,3-dioxolane at 25°: infrared, 3.02 μ (H-bonded OH). The proton nmr contained a singlet at τ 4.28 (relative area 1, OH), a singlet at τ 5.27 [relative area 2, $O-CH_2-O$ protons], a septuplet at τ 5.64 [relative area 1, $-CH(CF_3)_2$ proton].

Anal. Calcd $C_6H_8F_6O_3$: C, 29.76; H, 3.30; F, 47.08. Found: C, 30.01; H, 3.18; F, 46.79.

The residue was fractionated to give 59.6 g (74.3% based on 1,3-dioxolane) of 7,7,9,9-tetrakis(trifluoromethyl)-1,4,6-8-tetraoxaspiro[4.4]nonane (XII), bp 98–101° (45 mm). The infrared and proton nmr spectra of this compound were identical with those of XII reported previously and obtained from the reaction of HFA with 2-methoxy-1,3-dioxolane.[12]

5-(2-Hydroxyhexafluoro-2-propyl)-3,4-dihydro-2H-pyran (XV).—2-Methoxytetrahydropyran (23.2 g, 0.2 mole) and HFA (67.0 g, 0.4 mole) were heated in a bomb at 175° for 6 hr. The bomb was vented and the crude product (87.0 g) was fractionated to give 22.0 g of the hemiketal, 2-hydroxy-2-methoxy-hexafluoropropane, bp 90–94° (760 mm), with infrared and proton nmr spectra identical with that of an authentic sample prepared from methanol and HFA. The residue was distilled to give crystalline XV, bp 175–177° (760 mm), mp 68–69°, n^{25}_{D} 1.3910. The analysis and infrared and proton nmr spectra were identical with those of XV prepared from dihydropyran.

Compound XV was prepared directly by heating dihydropyran (16.8 g, 0.2 mole) and HFA (33.2 g, 0.2 mole) at 150° for 4 hr. The product (40.6 g, 81.2%) was essentially pure XV, mp 68–69° (recrystallized from petroleum ether). The infrared spectrum contained a strong OH band at 3.04 μ, a strong vinyl ether C=C band at 6.00 μ, and a cyclic ether band at 9.01 μ. The proton nmr spectrum conclusively showed that the 2-hydroxyhexafluoro-2-propyl group is at the 3 position of dihydropyran: multiplet at τ 2.00 (relative area 4, $C-CH_2-CH_2-C$ protons), singlet at τ 3.37 (relative area 1, OH), triplet at τ 3.99 (relative area 2, $O-CH_2-C$ protons), and a singlet at τ 6.88 (relative area 1, O-CH= proton). In another run using benzene as solvent at 125° for 6 hr, XV was prepared in 89.8% yield.

Anal. Calcd for $C_8H_8F_6O_2$: C, 38.26; H, 3.21; F, 45.39; mol wt, 251. Found: C, 38.40; H, 3.25, F, 45.27; mol wt (cryoscopic in benzene), 248, 250.

Reaction of HFA with Acetaldehyde Dimethyl Acetal—Dimethyl acetal (27.1 g, 0.3 mole) and excess HFA (150.0 g, 0.9 mole) were heated in a bomb at 140° for 6 hr. The product (116.0 g) was fractionated to give $CH_3OC(CF_3)_2OH$, bp 90–94° (760 mm). The infrared spectrum was identical with that of a sample of the hemiketal prepared from methanol and HFA. The high boiling fraction, bp 66° (20 mm) (35.5 g), was separated into two components by gas chromatography using a fluoroalkyl pyromellitate on Gas Chrom R column at 100° using a helium flow of 430 ml/min. The first peak, retention time 16.4 min (13.0 area %), was compound XVIII: infrared: 2.92 (OH), 6.05 μ (vinyl ether C=C), and no C=O band; proton nmr: τ 3.00 (doublet, O—*CH*=CH—), 5.12 (doublet, O—CH=*CH*—), 5.59 (singlet, OH), and 6.40 (singlet, 2 OCH_3).

Anal. Calcd for $C_6H_6F_6O_2$: C, 32.16; H, 2.70. Found: C, 32.32; H, 3.00.

The second component, retention time 36.4 min (76.7 area %), was compound XVI: bp 160° (760 mm); n^{25}_{D} 1.3454; infrared: 2.92 μ (OH), and no C=O or C=C bands; proton nmr: τ 4.40, singlet shifted by addition of CF_3COOH (OH), τ 5.2 [triplet, CH_2*CH*$(OCH_3)_2$], 6.58 (singlet, 2-OCH_3), 7.77 [doublet, –C–*CH*$_2$–$CH(OCH_3)_2$].

Anal. Calcd for $C_7H_{10}F_6O_3$: C, 32.82; H, 3.94; F, 44.50. Found: C, 32.97; H, 4.17; F, 44.72.

5-Dimethoxymethyl-2,2,4,4-tetrakis(trifluoromethyl)-1,3-dioxone (XXII).—Acrolein dimethyl acetal (30.6 g, 0.3 mole) and HFA (100.0 g, 0.6 mole) were heated in a bomb at 150° for 8 hr. The liquid product (86.0 g) was fractionated to give 24.4 g of a low boiler, 11.9 g (9.1%) of XXII, and 11.1 g of a polymeric residue. Compound XXII was purified by gas chromatography using a 6-ft biwall column packed with cyclohexanedimethanol succinate on Chromosorb P at 125° (retention time 3.5 min) to remove trace impurities: n^{25}D 1.3362. There was no hydrogen uptake in microhydrogenation, thus ruling out structures with unsaturation. The infrared spectrum contained no OH, C=C, or C=O bands.

The proton nmr was in agreement with the proposed structure, showing a doublet at τ 4.25 (relative area 1) [H–C(C)–(O–)$_2$], a doublet at 5.75 (relative area 2) (O–CH_2–C), a multiplet at 6.20 (relative area 1) (H–C(–C)$_3$), and two singlets at 6.33 and 6.44 (relative area 3 each) (–O–CH_3).

The mass spectrum shows a parent ion at *m/e* 434 as well as the following fragments which are in agreement with the proposed structure: *m/e* 403 (parent ion − $[CH_3O]^+$), 365 (parent ion − $[CF_3]^+$), 268 (parent ion − $[(CF_3)_2CO]^+$), 238 ($[(CH_3O)_2$-CH–CH–$C(CF_3)_2]^+$), 180 ($[C(CF_3)_2O–CH_2]^+$), 75 ($[(CH_3)_2CH]^+$).

Anal. Calcd for $C_{11}H_{10}F_{12}O_4$: C, 30.43; H, 2.32; F, 52.51; mol wt, 434. Found: C, 30.74; H, 2.52; F, 52.32; mol wt (freezing point in benzene), 424.

The Hydrolysis of Acetyl Fluoride

C. A. BUNTON AND J. H. FENDLER

Drpartment of Chemistry, University of California at Santa Barbara, Santa Barbara, California

Received February 21, 1966

The hydrolysis of acetyl fluoride can be followed kinetically in water by using a pH-Stat. For the spontaneous hydrolysis the activation energy is 12.5 kcal mole^{-1}, and activation entropy is −27 eu. Hydrogen and hydroxide ions catalyze hydrolysis. Uni-univalent salts of the strong acids retard hydrolysis, but sulfates assist it; magnesium and copper ions have little effect. Sodium fluoride is a general base catalyst, and sodium formate and pyridine catalyze hydrolysis by generating the more reactive acetyl derivatives. Sodium acetate generates the less reactive acetic anhydride and retards hydrolysis slightly. The hydrolysis is very similar mechanistically to those of the carboxylic anhydrides, but acetyl fluoride is more reactive than acetic anhydride in the acid, basic, and spontaneous hydrolyses.

In the course of recent work we have found that acetyl fluoride is an intermediate in the hydrolysis of acetic anhydride catalyzed by fluoride ion. We, therefore, measured the rate of its hydrolysis in water, because the only studies on this reaction had been made using aqueous acetone as solvent,[1] and our investigation has been extended to cover the kinetic effects of added reagents in order to elucidate the mechanistic details of the hydrolysis of acetyl fluoride.

Experimental Section

Materials.—Acetyl fluoride was prepared from acetyl chloride and zinc fluoride, and purified by repeated redistillation from sodium fluoride, and was stored in a polyethylene bottle under refrigeration.[1] Pyridine was dried over KOH and fractionally distilled and 2,6-lutidine, purified by forming the urea complex,[2] was generously supplied by Dr. R. H. DeWolfe. Inorganic salts were commercial samples, dried before use.

Kinetics.—The hydrolysis was followed by use of a pH-Stat.[3,4] A Sargent model S-30240 was used, and either disodium hydrogen or trisodium phosphate was used as titrant, as recommended by others.[3] When the titrant was sodium hydroxide the rate constants were erratic, and slightly high, because hydroxide ion reacts rapidly with acetyl fluoride.

For temperatures <15° a jacketed cell was used with magnetic stirring, and the temperature was maintained to 0.1° by circulating water from a constant temperature bath. Temperatures >15° were controlled by a thermistor-regulated constant-temperature block on the pH-Stat. For reactions at pH >7 carbon dioxide was excluded by passing a slow stream of nitrogen over the surface of the solution. Control experiments at pH <7 showed that the reaction rate was unaffected by this nitrogen stream, although bubbling it through the solution tended to remove some acetyl fluoride. The pH-Stat was calibrated at the temperature of the kinetic run using phosphate and phthalate buffers. The pH of the reaction solution was remeasured after each experiment, and the kinetic results were not used if the pH variation was >0.02. The calibration of the pH-Stat varied by <0.02 during-1 day.

Reaction was started by adding *ca.* 1/200 ml of a 50% solution of acetyl fluoride in dry dioxane from a hypodermic syringe. The initial concentration of acetyl fluoride was in the range 0.01 to 0.04 *M*. The first-order rate constants, k_ψ, were independent of the concentrations of acetyl fluoride and of the phosphate titrants. For the faster runs the speed of response of the pH-Stat is no longer very much greater than the reaction rate, it is then necessary to use low concentrations of acetyl fluoride, and so decrease the speed of the moving plunger in the buret of the pH-Stat. By this expedient we could follow reactions with half-lives down to *ca.* 1 min.

The values of k_ψ were calculated using the integrated first-order rate equation or Guggenheim's modification of it.[5]

Results

The values of k_ψ in the absence of added reagents are given in Table I, and are plotted *vs.* pH in Figure 1. The hydrolysis is catalyzed by hydrogen and hydroxide ions, and there is an appreciable spontaneous hydrolysis, and k_ψ follows the equation

$$k_\psi = k_{\rm H}[\overset{+}{\rm H}] + k_{\rm W} + k_{\rm OH}[\overset{-}{\rm OH}]$$

At 0.4° $10^3\,k_{\rm W} = 2.95$ sec^{-1}, and calculating the approximate concentrations of hydrogen and hydroxide ions at 0.4° from the relations

$$\text{pH} = -\log[\overset{+}{\rm H}], \text{ and } 14.93 - \text{pH} = \log[\overset{-}{\rm OH}]$$

we estimate $k_{\rm H} = 0.66$ l. mole^{-1} sec^{-1}, and $k_{\rm OH} = 5.7 \times 10^4$ l. mole^{-1} sec^{-1} (from a least-squares plot of k_ψ *vs.* $[\overset{-}{\rm OH}]$).

---

(1) C. G. Swain and C. B. Scott, *J. Am. Chem. Soc.*, **75**, 246 (1953).

(2) A. R. Butler and V. Gold, *J. Chem. Soc.*, 4362 (1961).

(3) M. L. Bender and M. S. Feng, *J. Am. Chem. Soc.*, **82**, 6318 (1960); L. Eberson, *Acta. Chem. Scand.*, **18**, 534 (1964).

(4) J. F. Kirsch and W. P. Jencks, *J. Am. Chem. Soc.*, **86**, 837 (1964).

(5) E. A. Guggenheim, *Phil. Mag.*, **2**, 538 (1926).