Those of 2,4-dinitrophenylhydrazones[11] and semicarbazones are given in Tables II and III, respectively.

The 2,4-dinitrophenylhydrazone of ethyl γ-oxosenecioate was submitted to the chromatographic separation on a paper impregnated with N,N-dimethylformamide, decalin saturated with the amide being used as a mobile phase.[12] After about 20 hours development a single spot (R_f 0.07) was observed. When the developing solvent was replaced with 30% tetrahydrofuran in ligroin (b.p. 80–100°),[13] the R_f value was 0.83, but the spot still remained single and the presence of other substances with different R_f values was not ascertained.

α-Methyl and α-Ethyl Monoesters of Mesaconic Acid.—A sample of methyl and ethyl γ-oxosenecioates was allowed to stand as a thin film on a watch-glass for about 1 week at room temperature. The autoxidation products solidified and melted at 51–52.5° and 65–66.5°, respectively. One recrystallization of each crude product from petroleum ether gave white crystals of α-methyl monoester, m.p. 52–53° (lit. 52°[14]), and α-ethyl monoester, m.p. 67–67.5° (lit. 67°[14]) of mesaconic acid, which afforded correct analyses for carbon and hydrogen.

Oxidation of Methyl γ-Oxosenecioate with Silver Oxide.—A solution of 7 g. (0.041 mole) of silver nitrate in 15 ml. of water was treated with a solution of 3.5 g. (0.0875 mole) of sodium hydroxide in 15 ml. of water under stirring. To the resulting suspension of silver oxide in water a solution of 2.5 g. (0.0195 mole) of methyl γ-oxosenecioate in 50 ml. of ether was added dropwise under continued stirring and ice-cooling, the reaction temperature being kept below 15°. After the addition was completed, stirring was continued for an additional 1 hour. The solids were removed by filtration and the filtrate was acidified with concentrated hydrochloric acid. The organic layer was separated, the aqueous one being saturated with sodium chloride and extracted with ether. The combined ethereal solutions were washed with saturated aqueous sodium chloride solution, dried over anhydrous sodium sulfate and evaporated to give 2.25 g. (88.5%) of colorless crystals with m.p. 191–200°.

The infrared spectrum of the crude oxidation product was completely identical with that of mesaconic acid and the absorptions characteristic of citraconic acid were absent; thus, the absorptions of the crude oxidation product and those of authentic specimen of mesaconic acid were 1700, 1680, 1638, 1351, 1297, 1265, 1233, 1132, 1017, 930, 914, 825 and 778 cm.$^{-1}$ (Nujol mull), while those of authentic specimens of citraconic acid were 1720, 1700, 1680, 1635, 1337, 1315, 1282, 1246, 1227, 1133, 1041, 1028, 926, 891, 820 and 765 cm.$^{-1}$ (Nujol mull).

Recrystallizations of the oxidation product from water gave a pure sample, m.p. 202°, mixed m.p. with mesaconic acid 202°. This also afforded correct analyses for carbon and hydrogen.

Volatile Carbonyl Constituents of a Watermelon Fruit.—An ordinary watermelon (*Citrullus vulgaris* Schrad.) fruit which weighed 6.5 kg. was found to consist of following parts: 2.4 kg. of rind, 0.08 kg. of seeds, 0.22 kg. of pressed cake and 3.8 kg. of juice. Concentrating the juice under reduced pressure gave 3.65 kg. of distillate and 0.14 kg. of red, viscous residue. The whole distillate was acidified with 200 ml. of concentrated sulfuric acid under stirring at 0–5° and then treated with an alcoholic solution of 0.8 g. of 2,4-dinitrophenylhydrazine. After standing overnight 350 mg. of yellow precipitates were collected by filtration and the mother liquor was extracted with ether. The ethereal extracts gave an additional 200 mg. of crystalline solid containing a small amount of oily product. Several recrystallizations of the combined dinitrophenylhydrazone mixture from ethanol containing ethyl acetate gave 380 mg. of yellow crystals melting at 168°, which were identified as 2,4-dinitrophenylhydrazone of acetaldehyde by means of a mixed m.p. with the authentic specimen.

The mother liquors of recrystallizations were concentrated and dissolved in a mixture of benzene–ether (10:1). This solution was chromatographed on activated alumina and the resulting fractions were examined by means of paper chromatography.[12]

The chromatography was carried out on a paper impregnated with N,N-dimethylformamide and developed with decalin saturated with the amide. The paper then was sprayed with sodium hydroxide solution in order to locate the spots.

Following fractions were isolated by the column-chromatography: fraction 1: Elution with petroleum ether gave a very small amount of light yellow needles melting at 91°, the R_f value on the paper being 0.9. This substance could not be identified due to the low yield.

Fraction 2: Elution with a mixture of petroleum ether–benzene (1:2) gave an additional 50 mg. of 2,4-dinitrophenylhydrazone of acetaldehyde. The total amount of the dinitrophenylhydrazone amounts to 430 mg. so that the content of acetaldehyde based on the whole fruit is 12 p.p.m.

Fraction 3: Elution with a mixture of benzene–ether (10:1) gave a very small amount of reddish-yellow crystals. The crystals afforded two spots on a paper chromatography. The R_f values were 0.2 and 0.3, respectively, in accord with the values of pure 2,4-dinitrophenylhydrazones of acetaldehyde and acetone, respectively, which were chromatographed under the same conditions. The acetone 2,4-dinitrophenylhydrazone could not be isolated.

Fraction 4: Elution with ethanol gave a brown oil which could neither be crystallized nor identified.

KYÔTO, JAPAN

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[11] Prepared according to R. L. Shriner and R. C. Fuson, "The Systematic Identifications of Organic Compounds," J. Wiley and Sons, Inc., New York, N. Y., 1948, pp. 170–171.

[12] I. Panayotov, *Perfumery Essent. Oil Record*, **49**, 233 (1958); see also L. Horner and W. Kirmse, *Ann.*, **597**, 48 (1955).

[13] R. G. Rice, G. J. Keller and J. G. Kirchner, *Anal. Chem.*, **23**, 194 (1951).

[14] R. Anschütz and J. Drugman, *Ber.*, **30**, 2649 (1897).

[CONTRIBUTION NO. 558 FROM THE CENTRAL RESEARCH DEPARTMENT, EXPERIMENTAL STATION, E. I. DU PONT DE NEMOURS AND CO.]

Fluoroketones. I

BY HOWARD E. SIMMONS AND DOUGLAS W. WILEY

RECEIVED SEPTEMBER 1, 1959

Fluoroketones have been shown to be versatile intermediates for the synthesis of new fluorine-containing structures. Ketals of unusual thermal and chemical stability have been prepared by a novel base-promoted ketalization. The synthesis was extended to dioxolanes, dioxanes, oxazolidines, oxathiolanes and their carbonyl-containing analogs. Fluoroketones reacted with diazomethane to give high yields of stable epoxides, and condensed readily with active methylene compounds and metallic acetylides. The chemistry of the condensation products was briefly examined.

Although a great number of partially and completely fluorinated ketones has been prepared by a variety of standard methods, the reported chemistry of these ketones,[1] most of which contained hydrogen-bearing α-carbons, does not reflect the inherent reactivity of the unusually modified carbonyl function. Observations made in these laboratories pointed out the desirability of

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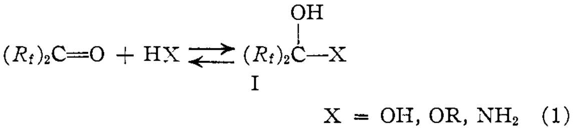
[1] P. Tarrant in J. H. Simons, "Fluorine Chemistry," Vol. II, Academic Press, Inc., New York, N. Y., 1954, pp. 213–320.

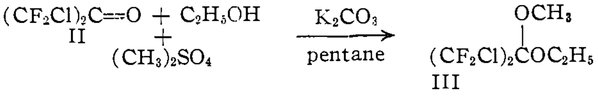
investigating the chemistry of α-fluoroketones,[2] particularly their use in synthesizing new fluorine-containing structures.

In α-fluoroketones, the presence of the highly electronegative fluorine atoms enhances the Lewis acid character of the carbonyl group so that isolable hydrates,[3,4] hemiketals[4] and ammonia adducts[4,5] can be obtained. Like many polyhaloketones, α-fluoroketones readily undergo the haloform reaction in aqueous base.[4,6] Other reported reactions of these ketones include catalytic reduction to fluoroalcohols[7,8] and the addition of organometallic reagents.[9] The latter is often accompanied by extensive reduction when the organometallic compound contains β-hydrogen atoms.[8,10] α-Fluoroketones do not form the usual derivatives with carbonyl reagents with the exception of hexafluoroacetone, whose semicarbazone has been reported.[11]

The formation of stable adducts of fluoroketones with water, aliphatic alcohols and ammonia indicates that equilibrium 1 lies far to the right, in contrast to the opposite behavior of aliphatic ketones. Furthermore, the hydroxyl group of the adduct I might be acidic[12] and potentially capable of alkylation. It was found that hemiketals of α-fluoroketones (I, X = OR) reacted with alkyl sulfates to give the previously undescribed α-fluoroketone ketals.[13] The reaction requires one equivalent of added base and appears to be the first example of a base-prompted ketalization. For example, *sym*-dichlorotetrafluoroacetone (II), ethanol and dimethyl sulfate underwent an exothermic reaction in pentane solution in the presence of potassium carbonate to give a 46% yield of 1,3-dichloro-2-ethoxy-2-methoxy-1,1,3,3-tetrafluoropropane (III). α-Fluoroketones are unique in that they can be converted directly to unsymmetrical ketals, $R_2C(OR')(OR'')$, uncontaminated by symmetrical ketals, $R_2C(OR')_2$ or $R_2C(OR'')_2$.

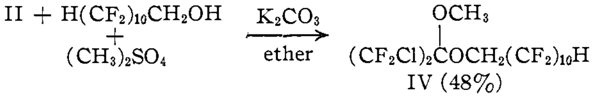


$$(R_f)_2C{=}O + HX \rightleftarrows \underset{\text{I}}{(R_f)_2\overset{\overset{OH}{|}}{C}{-}X} \qquad X = OH, OR, NH_2 \quad (1)$$

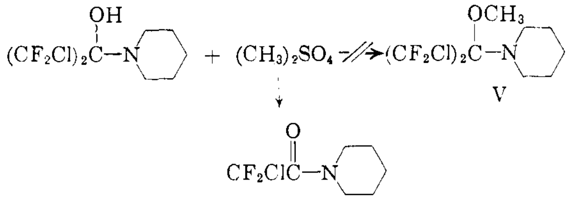


$$\underset{\text{II}}{(CF_2Cl)_2C{=}O} + C_2H_5OH + (CH_3)_2SO_4 \xrightarrow[\text{pentane}]{K_2CO_3} \underset{\text{III}}{(CF_2Cl)_2\overset{\overset{OCH_3}{|}}{C}OC_2H_5}$$

Best results were obtained when an inert solvent (pentane, ether, etc.) was employed in conjunction with a weak inorganic base. Alkyl halides, such as ethyl bromide and benzyl chloride, were generally less effective in the alkylation step; however, methyl iodide with silver oxide and ethanol gave low yields of III. Primary and secondary aliphatic alcohols were operable in the synthesis, and fluoroalcohols gave good yields of highly fluorinated ketals, such as IV. Additional examples are shown in Table I. Attempts to alkylate the adduct of an α-fluoroketone and a secondary amine with dimethyl sulfate to give the corresponding amine ether V led only to cleavage of the ketone.[14]

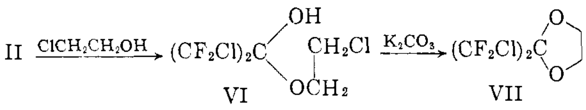


$$\text{II} + H(CF_2)_{10}CH_2OH + (CH_3)_2SO_4 \xrightarrow[\text{ether}]{K_2CO_3} \underset{\text{IV (48\%)}}{(CF_2Cl)_2\overset{\overset{OCH_3}{|}}{C}OCH_2(CF_2)_{10}H}$$

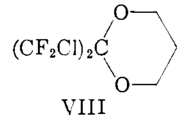


V

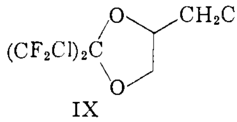
Cyclic ketals of α-fluoroketones could be prepared in excellent yields by the use of halohydrins. For example, ketone II reacted with ethylene chlorohydrin in the presence of potassium carbonate to give 2,2 - bis - (chlorodifluoromethyl) - 1,3 - dioxolane (VII) in 84% yield. Dioxanes and substituted dioxolanes, for example VIII and IX, could be prepared from trimethylene halohydrins and the appropriately substituted ethylene halohydrins, respectively. The successful expulsion of halide ion from the anion of a hemiketal, such as VI, undoubtedly is due to the intramolecular nature of the displacement leading to a five- or six-membered ring. 1,3-Dioxolanes were also obtained from hexafluoroacetone, *sym*-difluorotetrachloroacetone and trifluoroacetaldehyde.[13] Hexachloroacetone was cleaved under the mild reaction conditions, giving chloroform and 2-chloroethyl trichloroacetate (X).



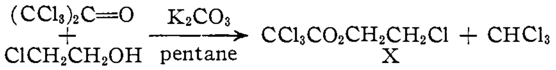
VI VII



VIII



IX



$$(CCl_3)_2C{=}O + ClCH_2CH_2OH \xrightarrow[\text{pentane}]{K_2CO_3} \underset{\text{X}}{CCl_3CO_2CH_2CH_2Cl} + CHCl_3$$

1,1,1-Trifluoroacetone (XI), which contains α-hydrogen, reacted with ethylene chlorohydrin and

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[2] The expression "α-fluoroketones" is used to designate fluorinated perhaloketones which bear at least one fluorine atom on each α-carbon.

[3] A. L. Henne, J. W. Shepard and E. J. Young, THIS JOURNAL, **72**, 3577 (1950).

[4] C. Woolf, Abstracts of Papers presented at American Chemical Society Meeting, New York N. Y., September, 1957, p. 23-M.

[5] W. R. Nes and A. Burger, THIS JOURNAL, **72**, 5409 (1950).

[6] W. H. Pearlson in J. H. Simons, "Fluorine Chemistry," Vol. I, Academic Press, Inc., New York, N. Y., 1950, p. 482.

[7] F. Bergmann and A. Kalmus, THIS JOURNAL, **76**, 4137 (1954).

[8] P. E. Hinkamp, II, Ph.D. Dissertation, The Ohio State University, 1954.

[9] E. T. McBee, J. F. Higgins and O. R. Pierce, THIS JOURNAL, **74**, 1387 (1952).

[10] E. T. McBee, J. F. Higgins and O. R. Pierce, *ibid.*, **74**, 1736 (1952).

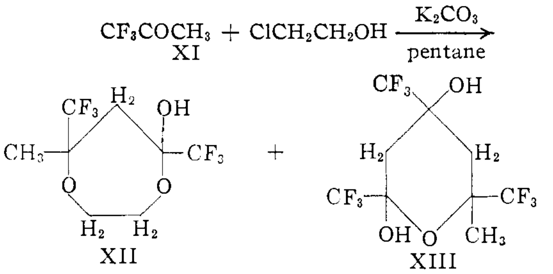
[11] A. T. Morse, P. B. Ayscough and L. C. Leitch, *Can. J. Chem.*, **33**, 453 (1955).

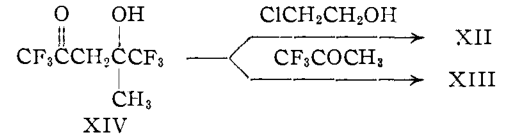
[12] Fluoroalcohols are, in general, more acidic (K_A) than aliphatic alcohols by a factor of 10^4; see E. T. McBee, W. F. Marzluff and O. R. Pierce, THIS JOURNAL, **74**, 444 (1952).

[13] D. R. Husted and A. H. Ahlbrecht, U. S. Patent 2,681,370 (1954), state thay they were unable to prepare the acetals of perfluoroaldehydes from the hemiacetals. However, with the methods described in this paper, the ethylene ketal of trifluoroacetaldehyde (see Table I) could be prepared.

[14] Although the ammonia adducts of α-fluoroketones appear to be stable, amine adducts slowly decompose to give an amide and a fluorocarbon; *cf.* M. Hauptschein and R. A. Braun, THIS JOURNAL, **77**, 4930 (1955).

potassium carbonate in pentane to give a liquid, seven-membered cyclic hemiketal XII, accompanied by a crystalline trimer XIII. Both XII and XIII appear to be formed through the intermediate diacetone alcohol XIV[15] in further base-promoted condensations with the chlorohydrin and the ketone, respectively. Henne and Hinkamp[8,16] have assigned structure XIII to the trimer obtained on treating XI with sodium in ether. The properties of Henne's trimer agree with those of XIII, and nuclear magnetic resonance and infrared spectral studies further confirmed the assigned structure.[17] The structure of the hemiketal XII was assigned on the basis of elemental analysis, spectral studies, the presence of one active hydrogen and hydrolysis to ethylene glycol.

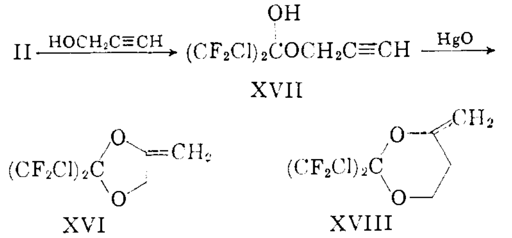




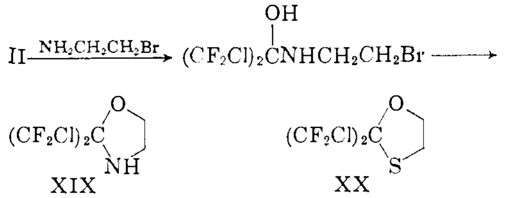
The cyclic and acyclic ketals of α-fluoroketones show extraordinary hydrolytic, oxidative and thermal stability. 1,3-Dichloro-2,2-dimethoxy-1,1-3,3-tetrafluoropropane (XV) and the related cyclic ketal VII are completely resistant to hydrolysis by concentrated sulfuric acid at their reflux temperatures of 150° and 170°, respectively. The ketals are also recovered unchanged after prolonged treatment at steam-bath temperature with 20% methanolic hydrochloric acid, 6 *N* nitric acid, 6 *N* sulfuric acid and 2 *N* sodium hydroxide. This extreme stability to acid hydrolysis is in marked contrast to the behavior of aliphatic ketals. Although the ketals of trifluoroacetaldehyde might be expected to show similar resistance to acids, boiling 2-trifluoromethyl-1,3-dioxolane with methanolic hydrochloric acid led to complete hydrolysis. Under basic hydrolysis conditions (1.0 *N* sodium methoxide in dry methanol, 25°, 1 week) the ethylene ketal of hexafluoroacetone was completely stable, whereas the ethylene ketal of 1,1,1,-4,4,4-hexafluorobutanone,[18] which contains α-hydrogens, underwent considerable degradation accompanied by the formation of fluoride ion.

Samples of the pure ketals VII and XV showed no tendency to oxidize in a stream of air at their boiling points even after one week. Dioxolane VII was inert at reflux temperature to iron, copper, tin, steel and brass. The dioxolane was also inert to magnesium and zinc under the usual conditions of dechlorinative ring closure. In controlled chlorinations of VII, the mono-, di-, tri- and tetrachlorinated dioxolanes could be prepared in good yields.

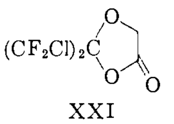
The ketone II reacted with propargyl alcohol in the presence of mercuric oxide to give 2,2-bis-(chlorodifluoromethyl) - 4 - methylene - 1,3 - dioxolane (XVI) in 84% yield. The reaction appeared to proceed *via* the initially formed hemiketal XVII which cyclized intramolecularly to the methylenedioxolane XVI. The corresponding dioxane XVIII was likewise synthesized from II and 3-butyn-1-ol.

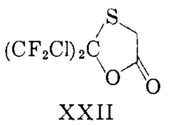


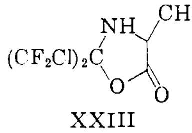
Other cyclic derivatives of α-fluoroketones have been synthesized by extensions of the base-induced ketalization. In contrast to the attempts to prepare acyclic 1,1-amine ethers, where only haloform cleavage was observed, the reaction of 2-bromoethylamine with II in the presence of potassium carbonate gave 2,2-bis-(chlorodifluoromethyl)-1,3-oxazolidine (XIX) in 84% yield. In marked contrast to aliphatic oxazolidines, the fluorinated oxazolidine XIX was quite stable to hydrolysis even in hot concentrated sulfuric acid solution and formed crystalline salts with anhydrous sulfuric acid and hydrogen chloride.[19] These salts reverted to the oxazolidine on the addition of water. The related oxathiolane XX was similarly synthesized in poor yield from 2-chloroethyl mercaptan.



The ready formation of cyclic derivatives of α-fluoroketones was further illustrated by the preparation of a series of fluorinated heterocyclic lactones. Ketone II reacted with α-substituted carboxylic acids, such as hydroxyacetic acid, mercaptoacetic acid and alanine to give the dioxolanone XXI, the oxathiolanone XXII and the oxazolidinone XXIII, respectively. The condensations were usually carried out in dimethylformamide using an excess of II in the presence of a basic catalyst, *e.g.*, sodium acetate. Similar hetero-


XXI


XXII


XXIII

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[15] E. T. McBee, P. H. Campbell, R. J. Kennedy and C. W. Roberts, THIS JOURNAL, **78**, 4597 (1956).

[16] A. L. Henne and P. E. Hinkamp, *ibid.*, **76**, 5147 (1954).

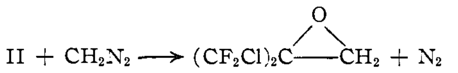
[17] Attempts to effect the bimolecular reduction of ketone XI with magnesium amalgam and with magnesious iodide led invariably to the trimer XIII, while treatment with zinc in glacial acetic acid gave 1,1,1-trifluoro-2-propanol.

[18] D. W. Chaney, U. S. Patent 2,522,566 (1950).

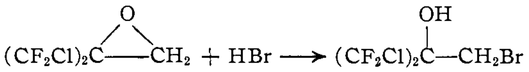
[19] E. D. Bergmann, *Chem. Revs.*, **53**, 309 (1953).

cyclic derivatives of aliphatic compounds have been described in the literature.[20,21]

The reaction of diazomethane with aldehydes and ketones has been extensively studied.[22] The presence of electronegative substituents on aldehydes and ketones has been reported to enhance the reaction with diazomethane and to give mainly oxides instead of the expanded ketones. In agreement with these observations, α-fluoroketones reacted vigorously with diazomethane to give fluoroepoxides in high yields.[23] Like the fluoroketals, these fluoroepoxides, such as 2,2-bis-(chlorodifluoromethyl)-oxirane (XXIV), were quite unreactive. They showed little tendency to polymerize, even in the presence of strong Lewis acids. The epoxide XXIV was heated to 225° at high pressure in the presence of phosphorus pentafluoride and was recovered unchanged. The epoxide was likewise recovered after treatment with hot, ethanolic hydrochloric acid, 6 *N* nitric acid, concentrated sulfuric acid at 100° and 50% potassium hydroxide solution. However, refluxing hydrobromic acid converted XXIV to the bromohydrin XXV.[24]

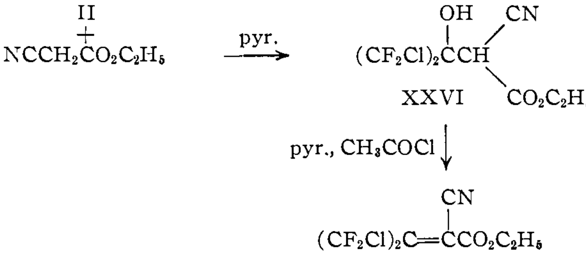


XXIV



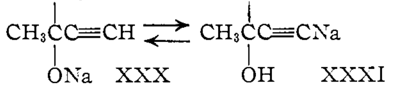
XXV

α-Fluoroketones also have been used successfully in carbanion condensation and addition reactions. Active methylene compounds, such as ethyl cyanoacetate, reacted with II and a pyridine catalyst to form the β-hydroxy ester XXVI, which could be dehydrated by treatment with pyridine in acetyl chloride solution to the unsaturated ester XXVII. Fluoroalcohols of the type $(R_f)_2C(OH)$-CH_2R generally dehydrate with difficulty, and the β-hydroxy esters are equally resistant to dehydration. The hydroxy ester XXVI was decomposed on direct treatment with bases, but by working in an acid medium (acetyl chloride) and using a deficiency of pyridine, the desired unsaturated ester could be obtained.



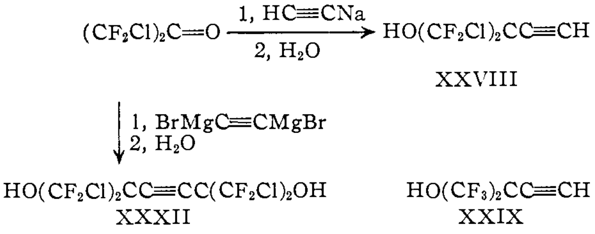
XXVII

α-Fluoroketones reacted smoothly with sodium acetylide and ethynylenedimagnesium bromide to give good yields of the corresponding acetylenic carbinols and diols, which represent an interesting class of fluoroörganic intermediates.[25,26] Ketone II reacted with freshly prepared sodium acetylide in ether suspension to give an 80% yield of the carbinol XXVIII. Hexafluoroacetone similarly gave the corresponding carbinol XXIX. This result contrasts with the work of Warner,[26] in which 1,1,1-trifluoroacetone (XI) was shown to give predominantly the corresponding diol with sodium acetylide in liquid ammonia.[27] When II was treated with ethynylene-dimagnesium bromide in ether, the corresponding diol XXXII was isolated in 53% yield along with 18% of carbinol XXVIII.



$$\mathrm{CH_3\overset{\displaystyle CF_3}{\underset{\displaystyle ONa}{C}}C{\equiv}CH} \rightleftarrows \mathrm{CH_3\overset{\displaystyle CF_3}{\underset{\displaystyle OH}{C}}C{\equiv}CNa}$$

XXX XXXI



$$\mathrm{(CF_2Cl)_2C{=}O} \xrightarrow[\text{2, H}_2\text{O}]{\text{1, HC}{\equiv}\text{CNa}} \mathrm{HO(CF_2Cl)_2CC{\equiv}CH}$$

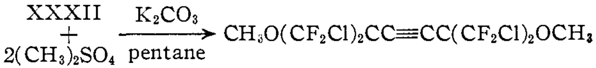
XXVIII

$$\Big\downarrow \begin{array}{l}\text{1, BrMgC}{\equiv}\text{CMgBr}\\ \text{2, H}_2\text{O}\end{array}$$

$$\mathrm{HO(CF_2Cl)_2CC{\equiv}CC(CF_2Cl)_2OH} \qquad \mathrm{HO(CF_3)_2CC{\equiv}CH}$$

XXXII XXIX

Alcohols XXVIII and XXXII were characterized by the preparation of their acetates and *p*-toluenesulfonates by modifications of the usual procedures. For instance, the *p*-toluenesulfonate of XXVIII could be prepared only by treating the carbinol with sodium hydride in benzene and then reaction of the soluble alcoholate with *p*-toluenesulfonyl chloride. The infrared spectrum of the product showed that displacement occurred by the oxygen of the carbinol and not by the acetylenic carbon. The carbinol and diol were etherified by treatment with alkyl sulfates and base. For example, diol XXXII gave the dimethyl ether XXXIII in good yield on treatment with dimethyl sulfate and potassium carbonate; XXXIII was very resistant to chemical or thermal degradation.



$$\begin{array}{c}\mathrm{XXXII}\\ +\\ \mathrm{2(CH_3)_2SO_4}\end{array} \xrightarrow[\text{pentane}]{\mathrm{K_2CO_3}} \mathrm{CH_3O(CF_2Cl)_2CC{\equiv}CC(CF_2Cl)_2OCH_3}$$

XXXIII

Carbinol XXVIII could be coupled by oxygen in the presence of aqueous cuprous ammonium chloride.[29] The crystalline diacetylenic diol XXXIV showed chemical behavior similar to XXXII.

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(20) E. J. Salmi and A. Pohjolainen, *Ber.*, **72B**, 798 (1939).

(21) B. Holmberg, *Arkiv. Kemi*, **2**, 567 (1950).

(22) C. D. Gutsche, "Organic Reactions," Vol. VIII, John Wiley and Sons, Inc., New York, N. Y., 1955, pp. 364–429.

(23) This reaction has subsequently been applied to the preparation of the epoxides from trifluoroacetaldehyde and 1,1,1-trifluoroacetone; see R. H. Groth, Ph.D. Dissertation, Ohio State University, 1956.

(24) This experiment was performed by Dr. J. F. Harris of these laboratories.

(25) H. M. Hill and E. B. Town, U. S. Patent 2,490,753 (1949), have reported that 1,1,1-trifluoroacetone (XI) reacted with ethynylmagnesium bromide to give 2-trifluoromethyl-3-butyn-2-ol.

(26) D. A. Warner, Ph.D. Dissertation, University of Florida, 1953.

(27) In liquid ammonia solution, the intermediate alcoholate XXX is presumably[26] converted to a large extent to the sodium acetylide XXXI, which reacts rapidly with more ketone to give the diol. Equilibria of this type were avoided in this work by conducting the additions in ether suspension, a system which generally fails for reactions of sodium acetylides with aliphatic ketones.[28]

(28) A. W. Johnson, "The Chemistry of the Acetylenic Compounds," Vol. I, Edward Arnold and Co., London, 1946, p. 12.

(29) See R. A. Raphael, "Acetylenic Compounds in Organic Synthesis," Butterworths Scientific Publications, London, 1955, p. 205.

$$\mathrm{XXVIII} + O_2 \xrightarrow[H_2O]{CuCl,\ NH_4Cl} HO(CF_2Cl)_2CC{\equiv}CC{\equiv}CC(CF_2Cl)_2OH$$

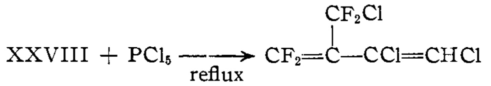
XXXIV

Alcohols XXVIII and XXXII were remarkably inert to a wide variety of reagents that normally lead to hydroxyl replacement. They were recovered unchanged after treatment with concentrated hydrochloric acid, phosphorus trichloride, phosphorus tribromide, phosphorus diiodide, thionyl chloride and the cuprous chloride–hydrochloric acid–sulfuric acid system. Similar reactions with phosphorus trichloride and phosphorus tribromide in pyridine led to extensive tar formation. Phosphorus pentachloride reacted cleanly with XXXII giving a product whose analysis showed the replacement of one hydroxyl group by chlorine. Spectral data suggested that the structure of the product was the expected monochloride XXXV.

$$\mathrm{XXXII} + PCl_5 \xrightarrow[\text{reflux}]{} Cl(CF_2Cl)_2CC{\equiv}CC(CF_2Cl)_2OH$$

XXXV

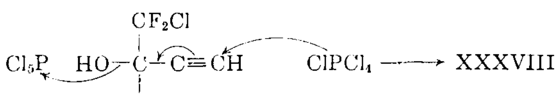
Carbinol XXVIII also reacted smoothly with phosphorus pentachloride to give a 54% yield of a product, $C_5HCl_3F_4$, corresponding to the replacement of hydroxyl by chlorine. However, on the basis of chemical and spectral data the product appears to be the 1,3-butadiene XXXVI, formed by multiple 1,3-allylic halogen transfers. The reaction may proceed through initial formation of the tertiary chloride XXXVII and then rearrangement to the allene XXXVIII,[30] which isomerizes to the more stable 1,3-butadiene XXXVI. However, the isolation of the unrearranged chloride XXXV from XXXII indicates that the tertiary chlorine atom does not readily rearrange. This observation suggests that XXXVII may not be an intermediate and that the allene XXXVIII might arise from the direct attack of phosphorus pentachloride on the terminal acetylenic carbon of XXVIII.



$$\mathrm{XXVIII} + PCl_5 \xrightarrow[\text{reflux}]{} CF_2{=}\overset{\displaystyle CF_2Cl}{\overset{|}{C}}{-}CCl{=}CHCl$$

XXXVI

$$\begin{tikzcd} \mathrm{XXVIII} \arrow[r] & Cl(CF_2Cl)_2CC{\equiv}CH\ (\mathrm{XXXVII}) \arrow[d] \\ & (CF_2Cl)_2C{=}C{=}CHCl\ (\mathrm{XXXVIII}) \arrow[r] & \mathrm{XXXVI} \end{tikzcd}$$



Acknowledgments.—We are indebted to Drs. J. J. Drysdale and W. D. Phillips of these laboratories for many helpful discussions and interpretations of nuclear magnetic resonance spectra during the course of this work. We also acknowledge the contribution of Dr. Drysdale, who helpfully carried out some of the experimental work.

Experimental

Fluoroketones.—*sym*-Difluorotetrachloroacetone (XXXIX) and *sym*-dichlorotetrafluoroacetone (II) were obtained from General Chemical Division, Allied Chemical and Dye Corp., Morristown, N. J., and were used without further purification. Hexafluoroacetone was prepared by the oxidation of perfluoroisobutylene with potassium permanganate using the published procedure of Morse.[11] 1,1,1-Trifluoroacetone was obtained from Columbia Organic Chemicals Co., Inc., Columbia, S. C.

The fluoroketones used in this work formed hydrates, hemiketals and ammonia derivatives in accordance with published observations.[3-6] For example, *sym*-dichlorotetrafluoroacetone quantitatively formed the ammonia adduct,[4] $(CF_2Cl)_2C(OH)(NH_2)$, m.p. 67–68°, when anhydrous ammonia was passed into the ketone. Recrystallization from ether did not change the melting point. The adduct was characterized by infrared and nuclear magnetic resonance spectral analyses.

Anal. Calcd. for $C_3H_3Cl_2F_4NO$: C, 16.7; H, 1.4; F, 35.2; N, 6.5. Found: C, 16.5; H, 1.6; F, 35.2; N, 6.5.

1,3-Dichloro-2-ethoxy-2-methoxy-1,1,3,3-tetrafluoropropane (III).—To 25.0 g. (0.13 mole) of II, 5.8 g. (0.13 mole) of absolute ethyl alcohol was slowly added with stirring. The resulting hemiketal was treated with 15.9 g. (0.13 mole) of dimethyl sulfate followed by 15 g. of potassium carbonate added in small portions over one hour. Small amounts of pentane were added to keep the mixture fluid. After 4 hours, the mixture, which no longer evolved carbon dioxide, was poured into 100 ml. of cold water and extracted with pentane. The dried pentane extract was concentrated and distilled to give 15.1 g. (46%) of III, b.p. 79–80° (51 mm.), $n^{25}D$ 1.3857.

Anal. Calcd. for $C_6H_8Cl_2F_4O_2$: C, 27.8; H, 3.1; F, 29.3. Found: C, 28.2; H, 3.6; F, 29.3.

The ethyl methyl ketal of II could also be synthesized in 25% yield by alkylating the ethyl hemiketal of II with methyl iodide in the presence of silver oxide. Alkylations with methyl iodide, ethyl bromide and benzyl chloride were unsuccessful using the weaker base potassium carbonate.

Additional examples of unsymmetrical alicyclic ketals, given in Table I, were synthesized in a similar manner using inert solvents such as ether or pentane to dissolve the initially formed hemiketal and alkylating with dimethyl sulfate and potassium carbonate. In the cases where dimethyl ketals were synthesized, excess methyl alcohol could be used as the solvent. The reaction products were then isolated in a normal manner. It was sometimes convenient to extract the ketals with concentrated sulfuric acid to remove impurities prior to distillation.

2,2-Bis-(chlorodifluoromethyl)-1,3-dioxolane (VII).—A mixture of 50.0 g. (0.25 mole) of II and 20.2 g. (0.25 mole) of ethylene chlorohydrin was stirred for 15 minutes, and 50 ml. of pentane was added. Thirty-five grams (0.25 mole) of potassium carbonate was added in portions over one hour, while the mildly exothermic reaction was controlled by external cooling. The mixture was allowed to stir for 2 hours and was poured into 150 ml. of water. The organic phase was separated, and the aqueous solution was extracted with two 80-ml. portions of pentane. The combined pentane solutions were washed with water and dried over anhydrous magnesium sulfate. Concentration of the pentane solution and fractionation of the residue gave 51.3 g. (84%) of VII, b.p. 171–172°, $n^{25}D$ 1.3896.

Anal. Calcd. for $C_5H_4Cl_2F_4O_2$: C, 24.7; H, 1.7; F, 31.3. Found: C, 24.9; H, 1.9; F, 31.4.

The ethylene ketal of II was also obtained in 30% yield by adding an equimolar mixture of II and ethylene chlorohydrin to a 15% aqueous potassium hydroxide solution and extracting the organic product with pentane.

Additional cyclic ketals, given in Table I, were synthesized in like manner from α-fluoroketones and the corresponding bromo- or chlorohydrin. These cyclic ketals were characterized by their compositions and by nuclear magnetic resonance and infrared spectral analyses.

Reaction of Hexachloroacetone with Ethylene Chlorohydrin.—A mixture of 20.0 g. (0.11 mole) of hexachloroacetone, 9.2 g. (0.11 mole) of ethylene chlorohydrin, 15.6 g. (0.11 mole) of potassium carbonate and 60 ml. of pentane was stirred overnight at room temperature. The reaction mixture was poured into 100 ml. of water, and the organic

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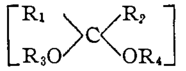
(30) See ref. 28, p. 71.

TABLE I

KETALS OF FLUOROKETONES

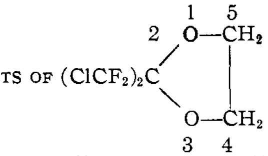


R_1	R_2	R_3	R_4	B.p. °C.	Mm.	$n^{25}D$	Yield,[a] %	Carbon, % Calcd.	Carbon, % Found	Hydrogen, % Calcd.	Hydrogen, % Found	Fluorine, % Calcd.	Fluorine, % Found
CF_2Cl	CF_2Cl	CH_3	CH_3	147–148		1.3829	47	24.5	24.8	2.5	2.9	31.0	31.1[b]
CF_2Cl	CF_2Cl	CH_3	$CH_3CH_2(CH_3)CH$	71.5	15	1.3965	40	33.5	33.5	4.2	4.2	26.5	27.3
CF_2Cl	CF_2Cl	CH_3	$CF_3(CF_2)_2CH_2$	73	25	1.3406	61	23.3	23.7	1.2	1.5	50.6	50.6
CF_2Cl	CF_2Cl	CH_3	$H(CF_2)_{10}CH_2$	150–154	12	1.3395	48	24.6	24.5	0.8	0.9	61.4	61.2[c]
$CF_3CF_2CF_2$	$CF_3CF_2CF_2$	CH_3	CH_3	72–73	48	1.3105	92	26.2	25.6	1.5	1.9	64.5	64.9
CF_3	CF_3	$-CH_2CH_2-$		99–100		1.3088	16	28.6	28.9	1.9	2.2	54.3	53.6
$CFCl_2$	$CFCl_2$	$-CH_2CH_2-$		65–66	1	1.4680	42	21.8	22.0	1.5	1.7	[d]	[d]
CF_3	H	$-CH_2CH_2-$		91.5–92		1.3353	11	33.8	32.8	3.6	3.9	40.1	39.9
CF_2Cl	CF_2Cl	$-CH_2CH_2CH_2-$		112–113	50	1.4109	37	28.0	28.1	2.4	2.6	29.6	28.5[e]
CF_2Cl	CF_2Cl	$-CH_2CHCH_2Cl$		74	6	1.4171	88[f]	24.7	24.7	1.7	2.1	26.1	26.3

[a] No attempts were made to determine optimum yields in the ketalization reactions. [b] Calcd.: Cl, 28.9. Found: Cl, 28.6. [c] Calcd.: Cl, 9.6; mol. wt., 743. Found: Cl, 9.3; mol. wt., 777. [d] Calcd.: Cl, 51.4. Found: Cl, 51.4. [e] Calcd.: Cl, 27.6. Found: Cl, 27.5. [f] A small amount of carbonyl-containing impurity was removed by heating briefly with 10% methanolic potassium hydroxide and redistilling.

TABLE II

CHLORINATION PRODUCTS OF



Position of chlorine	B.p., °C. (750 mm.)	$n^{25}D$	d^{25}	Carbon, % Calcd.	Carbon, % Found	Hydrogen, % Calcd.	Hydrogen, % Found	Chlorine, % Calcd.	Chlorine, % Found	Fluorine, % Calcd.	Fluorine, % Found
4-Chloro	179–180	1.4093	1.669	21.6	21.9	1.1	1.4	38.3	37.9	27.4	27.5
4,5(or 4,4)-Dichloro[a]	182–184	1.4159	1.692	19.3	19.7	0.7	0.9	45.5	45.0	24.4	24.9
4,4,5-Trichloro	199–200	1.4319	1.755	17.3	16.8	.3	.5	51.2	52.2	21.9	21.0
4,4,5,5-Tetrachloro	218–219	1.4466	1.811	15.8	16.1	.0	.2	55.9	55.9	20.0	20.1

[a] The nuclear magnetic resonance and infrared spectral analyses indicated the dichloro derivative to be a mixture of isomers.

phase was extracted with pentane. After the pentane extract was dried and concentrated, distillation of the residue gave 15.1 g. (59%) of 2-chloroethyl trichloroacetate (X), b.p. 57° (0.2 mm.), $n^{25}D$ 1.4782.

Anal. Calcd. for $C_4H_4Cl_4O_2$: C, 21.3; H, 1.8; Cl, 62.8. Found: C, 21.6; H, 2.0; Cl, 62.7.

Reaction of XI with Ethylene Chlorohydrin.—A mixture of 25.0 g. (0.22 mole) of XI and 18.0 g. (0.22 mole) of ethylene chlorohydrin was treated with 30.8 g. (0.22 mole) of potassium carbonate added in portions over one hour with stirring and external cooling. The mixture was stirred for 4 hours at room temperature and was poured into 150 ml. of water. The organic phase was extracted with pentane, and the pentane extracts were dried, concentrated and distilled. There was obtained 28 g. of a colorless oil, b.p. 110–120° (77 mm.), $n^{25}D$ 1.3697. Redistillation gave 13 g. of **5,7-bis-(trifluoromethyl)-5-hydroxy-7-methyl-1,4-dioxacycloheptane (XII)**, b.p. 69–70° (11 mm.), $n^{25}D$ 1.3675, and 12 g. of **2,4-dihydroxy-6-methyl-2,4,6-tris-(trifluoromethyl)-pyran (XIII)**, b.p. 77–78° (10 mm.), m.p. 107–108° (after four recrystallizations from pentane).

The dioxacycloheptane XII, which formed a salt with lithium hydride in ether, was characterized by its infrared spectrum. Strong unassociated hydroxyl absorption was observed at 2.83 μ, while bands attributable to olefinic or carbonyl absorption were absent. The nuclear magnetic resonance proton spectrum showed four peaks in the ratio 1:2:3:4, the peak of weight 1 being assignable to the hydroxyl proton and the peak of weight 3 to the single methyl group required by the assigned structure. The peaks of weights 2 and 4 were assigned to the methylene and ethylene groups, respectively, and occurred at their expected frequencies. The fluorine spectrum showed a single peak in the trifluoromethyl region.

Anal. Calcd. for $C_8H_{10}F_6O_3$: C, 35.8; H, 3.8; F, 42.5. Found: C, 35.8; H, 3.9; F, 42.6.

The pyran XIII, which also formed a salt with lithium hydride in ether, was a colorless, highly crystalline material that sublimed readily. The infrared spectrum showed strong unassociated hydroxyl absorption at 3.00 μ and no bands in the olefinic or carbonyl regions were detected. The nuclear magnetic resonance proton spectrum showed four peaks in the ratio 1:1:3:4, the two peaks of weight 1 occurring in the hydroxyl region of the spectrum. The peaks of weights 3 and 4 were assigned to the methyl and two methylene groups, respectively, and occurred at the expected frequencies. The fluorine spectrum was complex, but only showed absorption in the region attributable to fluorine bonded to saturated carbon.

Anal. Calcd. for $C_9H_9F_9O_3$: C, 32.2; H, 2.7; F, 50.8; mol. wt., 336. Found: C, 32.6; H, 3.0; F, 50.0; mol. wt., 318.

2,2-Bis-(chlorodifluoromethyl)-4-methylene-1,3-dioxolane (XVI).—To 120 g. (0.60 mole) of II, 33.6 g. (0.60 mole) of propargyl alcohol (b.p. 113–115°) was added over a 10-minute period with stirring and cooling. Two grams of yellow mercuric oxide was added in four portions at 5-minute intervals. The temperature was maintained at 35° for 4 hours. Initially it was necessary to cool the reacting solution, but after one hour external heat was applied. The dark colored reaction mixture was flash distilled under vacuum to give 144 g. of colorless liquid. Distillation through a spinning band column gave 129 g. (84%) of XVI, b.p. 51–53° (13 mm.), $n^{25}D$ 1.3982, d^{25}_{25} 1.514. The infrared absorption spectrum contained bands at 3.27(weak), 5.82 and 5.93 (medium, doublet) and 11.9–12.1 μ (very strong) associated with the $CH_2{=}C$ grouping which is a vinyl ether and is also exocyclic to a 5-membered ring.

Anal. Calcd. for $C_5H_4Cl_2F_4O_2$: C, 28.3; H, 1.6; F, 29.8; mol. wt., 255. Found: C, 28.5; H, 1.8; F, 29.7; mol. wt., 236, 245.

In a similar manner II was treated with 3-butyn-1-ol to give in 74% yield, **2,2-bis-(chlorodifluoromethyl)-4-methylene-1,3-dioxane**, b.p. 86–88° (22 mm.), $n^{25}D$ 1.4192, d^{25}_4 1.505. The infrared spectrum contained absorptions at 3.22(weak), 5.98(medium) and 11.88(strong)μ characteristic of the exocyclic $CH_2{=}C$ grouping which is also a vinyl ether.

Anal. Calcd. for $C_7H_6Cl_2F_4O_2$: C, 31.0; H, 2.2; Cl, 26.6; F, 28.2. Found: C, 31.7; H, 2.4; Cl, 26.5; F, 28.2.

Chlorination of VII.—To a stirred solution of 24.3 g. (0.10 mole) of VII in 200 ml. of carbon tetrachloride, cooled to $-13°$ by an internal cold finger and irradiated by an RS-4 Sunlamp, 7.1 g. (0.10 mole) of chlorine was added over a 3-hour period. The rate of addition was controlled to maintain a faintly yellow reaction solution. The solvent was removed under vacuum and the product distilled through a precision spinning-band column (U.S. Patent 2,712,520) to give 18.0 g. (57%) of **2,2-bis-(chlorodifluoromethyl)-4-chloro-1,3-dioxolane**, b.p. 179–180°, $n^{25}\text{D}$ 1.4050, d^{25} 1.657.

The more highly chlorinated products listed in Table II were synthesized by methods typified by the procedure above using more chlorine and higher reaction temperatures. These products were characterized by nuclear magnetic resonance and infrared spectral analyses in addition to the elemental analyses.

Reaction of II with Piperidine and Dimethyl Sulfate.—To a solution of 25.0 g. (0.13 mole) of II in 50 ml. of dry ether, 10.7 g. (0.13 mole) of piperidine in 50 ml. of dry ether was added dropwise with stirring. The temperature of the reaction mixture was maintained at $-20°$ by external cooling. When addition was complete, the pale yellow mixture was treated successively with 15.9 g. (0.13 mole) of dimethyl sulfate and 15 g. (0.11 mole) of potassium carbonate. The mixture was allowed to warm to room temperature and was stirred overnight. Water was added, and the organic phase was extracted with ether. Drying and concentration of the ether solution and then fractionation of the residue gave 2.5 g. (10%) of **1-(chlorodifluoroacetyl)-piperidine**, b.p. 63° (0.55 mm.), $n^{25}\text{D}$ 1.4512.

Anal. Calcd. for $C_7H_{10}ClF_2NO$: C, 42.6; H, 5.1; F, 19.2. Found: C, 42.7; H, 5.3; F, 19.3.

When the reaction was run at 0°, a 62% yield of the amide was obtained.

2,2-Bis-(chlorodifluoromethyl)-1,3-oxazolidine (XIX).—To a solution of 41.0 g. (0.20 mole) of 2-bromoethylamine hydrochloride in 75 ml. of dimethylformamide, 79.6 g. (0.40 mole) of II was added with cooling. To the chilled solution, 55.4 g. (0.40 mole) of powdered potassium carbonate was added in small portions over a one-hour period. After stirring for an additional two hours, the mixture was poured into 400 ml. of water and extracted with ether. The ethereal extracts were shaken with two 100-ml. portions of cold water and then dried over anhydrous magnesium sulfate. The solution now was distilled through a Vigreux column to obtain 47.3 g. (97%) of a yellow oil. After distillation through a spinning-band column, 40.8 g. (84%) of the oxazolidine was obtained, b.p. 138–139° (177 mm.), $n^{25}\text{D}$ 1.4122, d^{25} 1.596. The oxazolidine was soluble in concentrated sulfuric acid and formed a salt with anhydrous hydrogen chloride, which reverted to the unchanged oxazolidine upon shaking with water.

Anal. Calcd. for $C_5H_5Cl_2F_4NO$: C, 24.8; H, 2.1; F, 31.4; N, 5.8. Found: C, 24.8; H, 2.2; F, 31.0; N, 5.7.

2,2-Bis-(chlorodifluoromethyl)-1,3-oxathiolane (XX).—To a solution of 19.3 g. (0.20 mole) of 2-chloroethyl mercaptan in 50 ml. of ether, 80 g. (0.40 mole) of II was added slowly with cooling and stirring. A trace of sodium methoxide was added. The solution was stirred for one hour and then treated with 27.6 g. (0.20 mole) of potassium carbonate. The mixture was stirred overnight and then poured into water and extracted with ether. The ethereal extract was washed with 0.1 *N* sodium hydroxide, dried over anhydrous magnesium sulfate, and concentrated. The crude oxathiolane was distilled through a spinning-band column to give 17.3 g. (33%) of a foul smelling oil, b.p. 75–76° (9 mm.). Two redistillations were necessary to give an analytical sample of XX, b.p. 76° (9 mm.), $n^{25}\text{D}$ 1.4414.

Anal. Calcd. for $C_5H_4Cl_2F_4OS$: C, 23.2; H, 1.6; Cl, 27.4; S, 12.4. Found: C, 23.1; H, 1.9; Cl, 27.5; S, 12.2.

2,2-Bis-(chlorodifluoromethyl)-1,3-dioxolan-4-one (XXI).—To a solution of 30.4 g. (0.40 mole) of flake hydroxyacetic acid dissolved in 50 ml. of dimethylformamide, 89.0 g. (0.45 mole) of II was added with stirring and cooling. One gram of sodium acetate then was added, and the mixture was allowed to stand for 3 days. The reaction mixture was poured into 1 l. of water and extracted with methylene chloride. The combined methylene chloride extracts were washed successively with two 50-ml. portions of water and two 50-ml. portions of 2 *N* sodium hydroxide and then were dried over anhydrous magnesium sulfate. Concentration and distillation yielded 52.7 g. (61%) of XXI, b.p. 159–161°, $n^{25}\text{D}$ 1.3870. The infrared spectrum showed strong carbonyl absorption at 5.35 μ.

Anal. Calcd. for $C_5H_2Cl_2F_4O_3$: C, 23.4; H, 0.8; Cl, 27.6; F, 29.6; mol. wt., 257. Found: C, 23.5; H, 1.0; Cl, 27.6; F, 29.4; mol. wt., 239, 248.

2,2-Bis-(chlorodifluoromethyl)-5,5-dimethyl-1,3-dioxolan-4-one.—To a stirred solution of 39.8 g. (0.20 mole) of II in 75 ml. of ether, 25.4 g. (0.20 mole) of ethyl α-hydroxyisobutyrate was added with cooling. The solution was treated with 2 g. of anhydrous sodium acetate and then stirred for 48 hours. The mixture was filtered and flash distilled to separate the inorganic material. The crude oil was distilled through a spinning-band column to yield 24.1 g. of the ethyl hemiketal of II, b.p. 108°, $n^{25}\text{D}$ 1.3837, and 18.2 g. (64%) of the dioxolanone, b.p. 169°, $n^{25}\text{D}$ 1.3935. The infrared spectrum showed strong carbonyl absorption at 5.38 μ.

Anal. Calcd. for $C_7H_6Cl_2F_4O_3$: C, 29.5; H, 2.1; Cl, 24.9. Found: C, 29.6; H, 2.3; Cl, 25.0.

2,2-Bis-(chlorodifluoromethyl)-1,3-oxathiolan-5-one (XXII).—In a manner similar to that of preparing the dioxolanone XXI, XXII was prepared in 49% yield, b.p. 120° (50 mm.), $n^{25}\text{D}$ 1.4388, d^{25} 1.706. The infrared spectrum contained a strong carbonyl absorption band at 5.49 μ.

Anal. Calcd. for $C_5H_2Cl_2F_4O_2S$: C, 22.0; H, 0.7; F, 27.8; S, 11.7; mol. wt., 273. Found: C, 22.1; H, 0.8; F, 27.8; S, 11.9; mol. wt., 266, 276.

2,2-Bis-(chlorodifluoromethyl)-1,3-oxazolidin-5-one (XXIII).—A mixture of 13.4 g. (0.15 mole) of DL-alanine and 60.0 g. (0.30 mole) of II was treated with 50 ml. of dimethylformamide. The temperature rose to 45° and solution of the alanine occurred during the same time. The reaction mixture was heated to 60° for 3 hours and then taken up in 85 ml. of methylene chloride. The resulting solution was poured into 850 ml. of water and extracted with methylene chloride. The combined methylene chloride extracts were extensively washed with water, dried over anhydrous magnesium sulfate, and concentrated under vacuum at room temperature. The residual oil was distilled through a spinning-band column to yield 33.2 g. (83%) of XXIII, b.p. 109–110° (21 mm.). Redistillation of a center cut gave an analytical sample, b.p. 104° (16 mm.), $n^{25}\text{D}$ 1.4099, d^{25} 1.065. The infrared spectrum contained absorption peaks at 2.96 and 5.47 μ corresponding to N–H and C=O, respectively. The oxazolidinone appeared to be sensitive to light and air, slowly depositing a flocculent precipitate.

Anal. Calcd. for $C_6H_5Cl_2F_4NO_2$: C, 26.7; H, 1.9; F, 28.2; N, 5.2. Found: C, 27.0; H, 2.1; F, 27.9; N, 5.7.

When the same procedure was applied to glycine and II, the crude product decomposed extensively during attempted distillation with the formation of hydrogen fluoride and carbon dioxide.

Reaction of Fluoroketones with Diazomethane.—The reaction of diazomethane with fluoroketones proceeded readily at 0° in ethereal solutions. The procedure is typified by the reaction of II and diazomethane. To 0.45 mole of diazomethane in 800 ml. of ether cooled to 0°, 90.0 g. (0.45 mole) of II was cautiously added dropwise over a 2-hour period. The addition of each drop was accompanied by a vigorous evolution of nitrogen. The resulting faintly yellow solution was concentrated and distilled through a 15-cm. column packed with glass helices to yield 74.0 g. (78%) of **1,1-bis-(chlorodifluoromethyl)-oxirane (XXIV)**, b.p. 106–107°, $n^{25}\text{D}$ 1.3670. The oxirane was characterized by nuclear magnetic resonance and infrared spectral analyses.

Anal. Calcd. for $C_4H_2Cl_2F_4O$: C, 22.5; H, 1.0; Cl, 33.3. Found: C, 22.7; H, 1.0; Cl, 33.3.

In a like manner, **1,1-bis-(dichlorofluoromethyl)-oxirane** was synthesized in 93% yield from diazomethane and XXXIX, b.p. 90–91° (30 mm.), $n^{25}\text{D}$ 1.4522.

Anal. Calcd. for $C_4H_2Cl_4F_2O$: C, 19.5; H, 0.8; Cl, 57.7; F, 15.5 Found: C, 19.5; H, 1.0; Cl, 57.4; F, 15.6.

Similarly, perfluoroheptanone (XL) reacted with diazomethane to yield **1,1-bis-(perfluoropropyl)-oxirane**, b.p. 120–121°, $n^{25}\text{D}$ 1.2932. The nuclear magnetic resonance proton spectrum indicated only one type of hydrogen, and the corresponding fluorine spectrum was consistent with the perfluoropropyl group.

Hydrolysis of XXIV.—A mixture of 10.0 g. (0.05 mole) of XXIV and 9 ml. of 46% aqueous hydrobromic acid was stirred over a weekend and then refluxed several hours. The mixture was neutralized with 10% sodium biarbonate solution and extracted twice with 50 ml. of ether. The combined ether extracts were dried over anhydrous magnesium sulfate and concentrated. The residual oil was distilled to give 3.4 g. (34%) of unreacted epoxide, b.p. 105–113°, $n^{25}\text{D}$ 1.3706, and 4.7 g. (57%) of a bromohydrin, b.p. 167–169°, $n^{25}\text{D}$ 1.4303.

Anal. Calcd. for $C_4H_3BrCl_2F_4O$: Br, 27.2; Cl, 24.2. Found: Br, 27.3; Cl, 23.9.

Ethyl 4-Chloro-3-(chlorodifluoromethyl)**-2-cyano-4,4-**di**fluoro-2-butenoate (XXVII).**—A mixture of 25.0 g. (0.13 mole) of II and 14.2 g. (0.13 mole) of ethyl cyanoacetate was allowed to stand 15 minutes in a flask protected with a drying tube, and then 20.0 g. (0.25 mole) of acetyl chloride was added. Ten milliliters of pyridine was added dropwise over 45 minutes with rapid magnetic stirring. If stirring was inefficient, local tar formation occurred and none of the desired product was isolated. After stirring 30 minutes the mixture was warmed for 15 minutes on a steam-bath and then poured into 125 ml. of ice-water. The organic phase was extracted with two 100-ml. portions of pentane, which were combined and washed with 2% sodium bicarbonate solution and water. After drying and concentrating, the residue was distilled to give 20.6 g. (56%) of pure XXVII, b.p. 47–48° (0.2 mm.), $n^{25}\text{D}$ 1.4182.

Anal. Calcd. for $C_8H_5Cl_2F_4NO_2$: C, 32.7; H, 1.7; F, 25.9. Found: C, 32.4; H, 2.0; F, 26.1.

The butenoate was characterized by its infrared spectrum. The spectrum showed very weak nitrile absorption at 4.45 μ, consistent with previous observations of strong reductions in intensity of the ($C\equiv N$) stretching vibration in fluorine-containing nitriles.[31] Carbonyl absorption occurred at 5.67 μ with ($C=C$) at 6.19 μ.

1,1-Bis-(chlorodifluoromethyl)**-2-propyn-1-ol (XXVIII).**—A suspension of sodium acetylide in liquid ammonia was prepared in a flask equipped with stirrer, addition funnel and low-temperature condenser from 28.8 g. (1.12 moles) of sodium, 300 ml. of anhydrous ammonia and purified tank acetylene.[32] The ammonia was displaced with 300 ml. of absolute ether, and the low-temperature condenser was replaced by a water-jacketed condenser. A solution of 200 g. (1.00 mole) of II in 100 ml. of absolute ether was added dropwise with stirring over 2 hours, while the mixture refluxed gently. The reaction mixture was allowed to stir overnight, and 200 ml. of water was added cautiously. The organic phase was separated, and the aqueous layer was extracted with two 100-ml. portions of ether. The combined ether solutions were dried over anhydrous magnesium sulfate and concentrated. Final drying was accomplished by azeotropic distillation of benzene. Distillation of the residue gave 180 g. (80%) of the ethynylcarbinol, b.p. 41–42° (16 mm.), $n^{25}\text{D}$ 1.3940. Elemental analysis and the infrared spectrum of the product indicated contamination by less than 5% of a carbonyl-containing impurity that was extremely difficult to remove. The last traces of water and ether were also difficult to remove from the distilled carbinol. The product generally was used in further work after two distillations through an 18-in. spinning-band column. After distillation of small samples from phosphorus pentoxide, reasonably pure carbinol was obtained for analysis. The carbinol reacted exothermically on mixing with water and ether, giving indefinite hydrates and etherates, from which the carbinol could be recovered pure only with difficulty. Determination of pK_A in 50% aqueous ethanol gave values of 8.92 and 8.95, indicating the strongly acidic character of the fluoroalcohol.

Anal. Calcd. for $C_5H_2Cl_2F_4O$: C, 26.7; H, 0.9; F, 33.8; neut. equiv., 225. Found: C, 27.1; H, 1.9; F, 33.7; neut. equiv., 235.

The carbinol was characterized by its nuclear magnetic resonance proton and fluorine spectra and by its infrared spectrum: unassociated (OH), 2.90 μ; ($C\equiv C$), 4.70 μ (weak); acetylenic (C—H), 3.05 μ. The carbinol was soluble in pentane, ether, benzene, chloroform and water.

In a similar manner, **1,1-bis-(trifluoromethyl)-2-propyn-1-ol (XXIX)**, b.p. 87–88°, $n^{25}\text{D}$ 1.3125, was prepared in 16% yield from hexafluoroacetone[11] and sodium acetylide. This carbinol proved to be even more difficult to obtain analytically pure than the carbinol prepared from II. The infrared and nuclear magnetic resonance spectra again showed contamination with water, ether, and a carbonyl-containing compound. Satisfactory elemental analyses could not be obtained within 1% of the calculated values for carbon, hydrogen and fluorine.

1,1,4,4-Tetrakis-(chlorodifluoromethyl)**-2-butyn-1,4-diol (XXXII).**—Ethynylenedimagnesium bromide was prepared in a flask equipped with a stirrer, addition funnel and reflux condenser from 82.0 g. (0.75 mole) of ethyl bromide, 20.2 g. (0.83 mole) of magnesium turnings, 240 ml. of anhydrous ether and purified tank acetylene.[33] A solution of 100 g. (0.50 mole) of II in 100 ml. of anhydrous ether was added dropwise over one hour with stirring and external cooling. The mixture was stirred for 24 hours at room temperature, and 200 ml. of 5 *N* hydrochloric acid was added cautiously with cooling. The organic phase was separated, and the aqueous layer was extracted with three 100-ml. portions of ether. The combined ether solutions were dried over anhydrous magnesium sulfate and concentrated. Distillation of the residue gave 20.5 g. (18%) of XXVIII, b.p. 40–41° (18 mm.), $n^{25}\text{D}$ 1.3862. The light tan pot residue crystallized and weighed 75.5 g. (71%). Recrystallization from ether gave 56.4 g. (53%) of the pure, colorless diol, m.p. 51–52°.

Anal. Calcd. for $C_8H_2Cl_4F_8O_2$: C, 22.7; H, 0.5; Cl, 33.5; F, 35.9. Found: C, 22.9; H, 1.0; Cl, 33.2; F, 35.7.

The infrared spectrum of the diol showed, below 7.0 μ, only a sharp unassociated hydroxyl band at 2.90 μ and the nuclear magnetic resonance proton and fluorine spectra were in accord with the assigned structure. The diol was soluble in pentane, ether, benzene, chloroform and partially soluble in water, with which it hydrated strongly. Determination of acidity in 50% aqueous ethanol gave values of pK_{A_1} 7.35, 7.45 and pK_{A_2} 10.03, 10.05, the diol being titratable as a dibasic acid.

3-Acetoxy-3,3-bis-(chlorodifluoromethyl)**-propyne.**—A mixture of 15.0 g. (0.07 mole) of XXVIII and 7.9 g. (0.10 mole) of acetyl chloride was cooled to 0°. Under anhydrous conditions 6 ml. of pyridine was added dropwise with vigorous magnetic stirring. The addition of excess pyridine or slow stirring caused extensive tarring and a reduction in yield. The mixture was allowed to stir at 0° for 2 hours, and 100 ml. of ice-water was added. The organic phase was extracted with three 50-ml. portions of pentane, which were combined and washed successively with 3% hydrochloric acid, 3% sodium bicarbonate and water. After drying and concentrating the pentane solution, the residue was distilled to give 16.5 g. (93%) of the acetate, b.p. 66–67° (14 mm.). $n^{25}\text{D}$ 1.4031. The infrared spectrum showed strong acetylenic (C–H) absorption at 3.05 μ, strong ($C\equiv C$) at 4.68 μ and ester ($C=O$) at 5.54 μ.

Anal. Calcd. for $C_7H_4Cl_2F_4O_2$: C, 31.5; H, 1.5. Found: C, 31.3; H, 1.8.

3,3-Bis-(chlorodifluoromethyl)**-3-**(*p*-toluenesulfonoxy)**-propyne.**—A solution of 10.00 g. (0.044 mole) of XXVIII in 10 ml. of dry benzene was added dropwise to a stirred suspension of 1.06 g. (0.044 mole) of sodium hydride in 60 ml. of dry benzene. When addition was complete, the mixture was stirred for one hour to give a clear solution of the sodium salt. *p*-Toluenesulfonyl chloride (8.48 g., 0.044 mole) was added, and the mixture was stirred at reflux for 2 days, during which time sodium chloride slowly precipitated. After cooling the mixture was washed with 5% sodium bicarbonate solution and water and was dried over anhydrous magnesium sulfate. Concentration and short-path distillation gave 11.2 g. (66%) of the *p*-toluenesulfonate as a viscous oil which solidified on standing. Sublimation gave a colorless, analytical sample, m.p. 43–44°. The infrared spectrum showed acetylenic (C–H) absorption at 3.05 μ, strong ($C\equiv C$) absorption at 4.68 μ, and no bands attributable to (O–H), indicating that only the hydroxyl group was involved in the reaction.

Anal. Calcd. for $C_{12}H_8Cl_2F_4O_3S$: C, 38.0; H, 2.1; F, 20.0. Found: C, 38.0; H, 2.4; F, 20.3.

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(31) D. G. Weiblen in J. H. Simons, "Fluorine Chemistry," Vol. II, Academic Press, Inc., New York, N. Y., 1954, p. 453.

(32) T. L. Jacobs in "Organic Reactions," Vol. V, John Wiley and Sons, Inc., New York, N. Y., 1949, p. 48.

(33) G. du Pont, *Ann. chim. phys.*, [8] **30**, 498 (1913).

In a similar manner, XXIX gave **3,3-bis-(trifluoromethyl)-3-(*p*-toluenesulfonoxy)-propyne**, m.p. 36–37° (from pentane), in 78% yield.

Anal. Calcd. for $C_{12}H_8F_6O_3S$: C, 41.6; H, 2.3. Found: C, 41.9: H, 2.5.

The acetylenic diol XXXII gave **1,4-bis-(*p*-toluenesulfonoxy)-1,1,4,4-tetrakis-(chlorodifluoromethyl)-2-butyne**, m.p. 189–190° (from acetone), in 75% yield by the same method.

Anal. Calcd. for $C_{22}H_{14}Cl_4F_8O_6S_2$: C, 36.1; H, 1.9. Found: C, 36.1; H, 1.8.

1,4-Dimethoxy-1,1,4,4-tetrakis-(chlorodifluoromethyl)-2-butyne (XXXIII).—In an attempt to prepare a bis-ketal of XXXII with II and dimethyl sulfate, ketone II did not enter into the reaction, and the dimethyl ether of the glycol was formed smoothly.

A mixture of 4.7 g. (0.02 mole) of II, 5.0 g. (0.01 mole) of XXXII, 3.0 g. (0.02 mole) of dimethyl sulfate, and 1.4 g. (0.01 mole) of potassium carbonate was stirred at room temperature for 20 hours. The mixture was poured into 100 ml. of water, and the organic phase was extracted with two 50-ml. portions of pentane. The pentane extracts were dried and concentrated. Distillation of the residue gave 2.5 g. (46%) of XXXIII, b.p. 67° (0.2 mm.), $n^{25}D$ 1.4061. The infrared and nuclear magnetic resonance spectra were in accord with the assigned structure.

Anal. Calcd. for $C_{10}H_6Cl_4F_8O_2$: C, 26.6; H, 1.3; F, 33.6. Found: C, 26.3; H, 1.5; F, 33.5.

1,1,6,6-Tetrakis-(chlorodifluoromethyl)-2,4-hexadiyn-1,6-diol (XXXIV).—A mixture of 22.5 g. (0.10 mole) of XXVIII, 25.0 g. (0.13 mole) of cuprous chloride, 40.0 g. (0.75 mole) of ammonium chloride and 100 ml. of water was placed in a Parr shaker bottle and agitated under a small, positive oxygen pressure. The initially dark, heterogeneous mass became pale green after one hour, and the smooth oxygen absorption ceased abruptly. The green suspension was extracted with six 100-ml. portions of ether, which were combined and dried over anhydrous magnesium sulfate. Concentration and distillation gave 11.5 g. (51% recovery) of the carbinol. The pot residue crystallized and was purified by sublimation and recrystallization from ether, giving 8.7 g. (79%, based on recovered carbinol) of the diacetylenic diol XXXIV, m.p. 79–80°. The infrared and nuclear magnetic resonance spectra were in accord with the assigned structure.

Anal. Calcd. for $C_{10}H_2Cl_4F_8O_2$: C, 26.8; H, 0.5; F, 33.9. Found: C, 27.0; H, 0.8; F, 34.2.

Reaction of XXVIII with Phosphorus Pentachloride.—A mixture of 50.0 g. (0.22 mole) of XXVIII and 52.0 g. (0.25 mole) of phosphorus pentachloride was heated on a steam-bath. At approximately 50° an exothermic reaction occurred and the phosphorus pentachloride slowly dissolved to give a clear, yellow liquid. The mixture was heated under gentle reflux for one hour and was then poured into a separatory funnel containing 400–500 g. of crushed ice. After shaking for 2 minutes, the organic phase was extracted with 200 ml. of pentane. The pentane solution was washed with a little ice-water and dried over anhydrous magnesium sulfate. Concentration and distillation of the residue gave 4.3 g. (9% recovery) of XXVIII and 26.6 g. (54%, based on recovered carbinol) of **3-(chlorodifluoromethyl)-,1,2-dichloro-4,4-difluoro-1,3-butadiene (XXXVI)**, a colorless, lachrymatory oil, b.p. 43° (38 mm.), $n^{25}D$ 1.4152.

Anal. Calcd. for $C_5HCl_3F_4$: C, 24.7; H, 0.4; Cl, 43.7; F, 31.2. Found: C, 24.8; H, 0.5; Cl, 43.6; F, 31.2.

The structure of the butadiene was assigned on the basis of mechanistic considerations and an analysis of the ultraviolet, infrared and nuclear magnetic resonance spectra.

The ultraviolet spectrum of the diene showed no peaks above 190 mμ in heptane solution, but there was evidence that an absorption maximum may occur just below 190 mμ. The spectrum of XXXVI showed only a smooth rise in absorption intensity from 300 to 190 mμ. In these laboratories, similar spectra have been observed in hexafluoro-1,3-butadiene and other butadienes highly substituted with fluorine and chlorine.

The infrared spectrum of XXXVI showed vinyl (C–H) at 3.23 μ and strong ($F_2C{=}C$) absorption at 5.77 μ. Another (C═C) absorption band occurred at 6.20 μ and was weak.[34]

The nuclear magnetic resonance proton spectrum showed a single vinyl (C–H), while the fluorine spectrum showed two equal peaks that could be assigned to the two fluorine environments present in XXXVI.

Reaction of XXXII with Phosphorus Pentachloride.—A mixture of 10.0 g. (0.02 mole) of XXXII and 9.8 g. (0.05 mole) of phosphorus pentachloride was placed in a flask equipped with a reflux condenser and drying tube and was heated on a steam-bath. At approximately 50° an exothermic reaction occurred, and the phosphorus pentachloride slowly dissolved to give a clear, yellow liquid. The mixture was heated under reflux for 30 minutes and was then poured into a separatory funnel containing 200–300 g. of crushed ice. After shaking for 2 minutes, the organic phase was extracted with hexane. The hexane solution was washed with a little 2% sodium bicarbonate solution and water and was dried over anhydrous magnesium sulfate. Concentration and distillation of the residue gave 6.0 g. (58%) of **4-chloro-1,1,4,4-tetrakis-(chlorodifluoromethyl)-2-butyn-1-ol (XXXV)**, b.p. 69–70° (1.7 mm.), $n^{25}D$ 1.4300.

Anal. Calcd. for $C_8HCl_5F_8O$: C, 21.7; H, 0.2; Cl, 40.1; F, 34.4. Found: C, 21.8; H, 0.8; Cl, 40.2; F, 33.9.

The infrared spectrum of XXXV showed no (C═C) or (C═C═C) absorption. No (C—H) bands of any kind were present, but a strong, unassociated (O—H) band at 2.83 μ was present. Weak (C≡C) absorption occurred at 4.60 μ.[30] The nuclear magnetic resonance fluorine spectrum showed two peaks of equal intensity associated with the two kinds of ($-CF_2Cl$) groups in XXXV. The region attributable to ($C{=}CF_2$) was blank in the spectrum.

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(34) See also R. N. Haszeldine, *J. Chem. Soc.*, 4423 (1952). Hexafluoro-1,3-butadiene shows terminal ($CF_2{=}C$) absorption at 5.65 μ, corresponding to the terminal ($CF_2{=}C$) in XXXVI at 5.77 μ. The weaker absorption at 6.20 μ, which appears to correspond to a partially conjugated double bond, is in accord with the presence of the chlorine atoms in the (CCl═CHCl) group. Accurate scale atomic models (Stuart–Briegleb) show that XXXVI is greatly strained in either planar form, so that absorption arising from the (CCl═CHCl) group would appear more nearly like unconjugated (C═C) absorption.