and 8 ml of 10% aqueous sodium hydroxide. The reaction mixture was stirred overnight and filtered, and the solvent was removed at reduced pressure to afford 31.8 g (97%) of cyclopentenol **5**. Material purified by distillation exhibited these properties: bp 65–67° (3.5 mm); n^{25}_{D} 1.4658; $\lambda_{\max}^{\text{film}}$ 3.00, 6.08, 9.71, 10.29, and 11.75 μ; nmr signals at τ 4.68 (1 H, C=CH), 5.36 (1 H, CHOH), 5.95 (1 H, OH), and 8.97 (6 H, doublet, J = 7 Hz, CHCH$_3$). Because the material was only moderately stable and decomposed on storage after several days, it was converted directly into bicyclic alcohol **7** without analysis.

Demethyl-*cis*-sabinene Hydrate (7).—An adaptation of the procedure of Dauben and Berezin[14] was employed. A nitrogen blanketed[19b] slurry of 7.84 g (0.12 mol) of zinc–copper couple[23] and a crystal of iodine in 60 ml of anhydrous ether was treated rapidly with 26.4 g (0.1 mol, 8 ml) of freshly distilled methylene iodide. The rapidly stirred mixture was heated at 40° for 0.5 hr. A solution of 6.42 g (0.05 mol) of pentenol **5** in 16 ml of ether was added dropwise at a rate sufficient to maintain gentle reflux without external heat (*ca.* 0.5 hr). Following addition, the reaction was refluxed for 1 hr, cooled, treated cautiously with excess saturated, aqueous ammonium chloride, and filtered. The solid was washed well with ether and the resulting filtrate was washed with two portions of 10% aqueous sodium carbonate. The combined aqueous layers were back extracted, and the combined ether layers were washed with brine and dried over magnesium sulfate. Solvent removal and subsequent distillation afforded three fractions: (1) 0.45 g, bp 25–40° (1 mm), containing 9% alcohol **7** by glpc (150°); (2) 0.34 g, bp 40–56° (1 mm), containing 75% alcohol **7**; (3) 4.62 g (66%) bp 56–57° (1 mm), containing 95% alcohol **7**. This material was purified by distillation, bp 60° (1 mm), and glpc (150°): n^{25}_{D} 1.4655; $\lambda_{\max}^{\text{film}}$ 3.00, 9.49, and 9.75 μ; nmr signals at τ 5.55 (1 H, multiplet, CHOH), 7.90 (1 H, OH), 9.08 (3 H, doublet, J = 6 Hz, CHCH$_3$), 9.14 (3 H, doublet, J = 6.5 Hz, CHCH$_3$), 9.32 [1 H, triplet, J(C-6-*endo* H, C-1 H) = 4.5 Hz, J(C-6-*endo* H, C-6-*exo* H) = 4.5 Hz, C-6-*endo* H], and 9.69 [1 H, quartet, J(C-6-*exo* H, C-1 H) = 7.7 Hz, J(C-6-*endo* H, C-6-*exo* H) = 4.5 Hz, C-6-*exo* H].[24,25]

Anal. Calcd for $C_9H_{16}O$: C, 77.09; H, 11.50. Found: C, 76.9; H, 11.6.

Sabina Ketone (9).—A solution of 4.62 g (0.033 mol) of alcohol **7** in 75 ml of acetone maintained at 0–5° was oxidized with 9 ml of Jones reagent[16] over a 15-min period. The resulting solution was stirred an additional 10 min at 0–5° and added to brine. Several ether extracts were washed with saturated aqueous sodium bicarbonate, the aqueous layers were back extracted, and the total ether was washed with brine and dried over magnesium sulfate. Removal of the solvent and distillation afforded 4.05 g (89%) of faint yellow sabina ketone, bp 67–70° (5 mm), n^{25}_{D} 1.4654 (lit.[3] n^{25}_{D} 1.4672), which showed 96% purity by glpc (150°). Pure material obtained by redistillation, bp 70° (5 mm), and glpc (150°) collection exhibited these spectral properties: $\lambda_{\max}^{\text{film}}$ 3.30, 5.79, 8.49, 9.79, 10.93, and 12.86 μ; nmr signals at τ 7.70–8.16 (3 H), 8.25–8.70 (2 H), and 8.73–9.20 (9 H). A pure sample of sabina ketone prepared by ozonation of naturally occurring sabinene[17] had an index of refraction of n^{25}_{D} 1.4645 and an infrared spectrum superimposable with the synthetic material.

Anal. Calcd for $C_9H_{14}O$: C, 78.21; H, 10.21. Found: C, 78.4; H, 10.3.

Sabinene (8).—A slurry of 1.24 g (0.032 mol) of a 61% sodium hydride–mineral oil dispersion in 40 ml of dimethyl sulfoxide was heated at 70° under nitrogen[19b] for 1 hr. The resulting base solution was cooled to 0–5° and treated with a warm solution of 11.9 g (0.033 mol) of methyltriphenylphosphonium bromide in 40 ml of dimethyl sulfoxide. The semisolid mixture slowly warmed to 25–27° where solution took place. Stirring was continued for 20 min at 25–27°, and a solution of 1.30 g of 74% pure sabina ketone (0.007 mol) in 20 ml of dimethyl sulfoxide was added dropwise over 5 min. The resulting dark yellow solution was stirred at 25–27° for 3 hr, and added to water, and the product isolated with pentane. Several extracts were combined, washed with water and brine, and dried over magnesium sulfate. The solvent was removed by distillation and the total crude was passed through a chromatographic column containing 100 ml of Florisil. One 300-ml pentane fraction was collected and the pentane removed by distillation to afford 2.9 g of colorless, residual oil which on evaporative distillation afforded 880 mg (93% material balance) of colorless product, bp 60–70° (16 mm), which showed 79% purity by glpc (90°). A sample purified by glpc (90°) had the properties n^{25}_{D} 1.4654 [lit.[26] bp 69° (30 mm), n^{20}_{D} 1.4681]; $\lambda_{\max}^{\text{film}}$ 3.29, 6.04, 7.28, 7.37, 9.78, and 11.53 μ; nmr signals at τ 5.27, 5.46 (2 H, C=CH$_2$), 9.10 (3 H, doublet, J = 6 Hz, CHCH$_3$), 9.18 (3 H, doublet, J = 7 Hz, CHCH$_3$), and 9.34 and 9.40 (2 H, C-6 H's). A purified sample of natural sabinene[17] exhibited superimposable spectra with those reported above.

Anal. Calcd for $C_{10}H_{16}$: C, 88.16; H, 11.84. Found: C, 88.0; H, 11.8.

***cis*- and *trans*-Sabinene Hydrate (10, 11).**—A solution of 2.94 g (0.021 mol) of sabina ketone (88% pure) in 16 ml of ether was added over 10 min to 37 ml of a 1.62 *M* solution of ethereal methyllithium and 26 ml of ether contained under a nitrogen atmosphere.[19b] The resulting mixture was refluxed for 1 hr, cooled, and poured onto excess ice. Isolation[19f] afforded 3.30 g (100% material balance) of faint green oil composed of solvent, an unknown [17% (10% present in starting material)], *trans*-sabinene hydrate (**11**, 13%), *cis*-sabinene hydrate (**10**, 71%), and sabina ketone (**9**, 1%). A run using 97% pure sabina ketone gave 11% *trans*- and 84% *cis*-sabinene hydrate. The crude products were chromatographed on 500 ml of Florisil with glpc (125°) monitoring of fractions. Subsequent combination and distillation afforded 680 mg of a mixture of unknown and isomeric alcohols **10** and **11** and 550 mg of pure *cis*-sabinene hydrate (**10**).

Pure *cis* isomer **10** exhibited the properties which follow: n^{25}_{D} 1.4632; $\lambda_{\max}^{\text{film}}$ 3.00, 7.36, 8.85, 9.50, 10.12, 10.51, and 10.78 μ; nmr signals at τ 7.55 (1 H, OH), 8.70 (3 H, HOCCH$_3$), 9.08 (3 H, doublet, J = 6.8 Hz, CHCH$_3$), 9.12 (3 H, doublet, J = 6.5 Hz, CHCH$_3$), 9.34 [1 H, quartet, J(C-6-*endo* H, C-1 H) = 4.0 Hz, J(C-6-*endo* H, C-6-*exo* H) = 4.9 Hz, C-6-*endo* H], and 9.71 [1 H, quartet, J(C-6-*exo* H, C-1 H) = 8.0 Hz, J(C-6-*endo* H, C-6-*exo* H) = 4.9 Hz, C-6-*exo* H].[24,25] Pure *cis*-sabinene hydrate as described by Eastman[18] exhibited spectra identical with those described above.

Anal. Calcd for $C_{10}H_{18}O$: C, 77.86; H, 11.76. Found: C, 77.7; H, 11.8.

Pure *trans*-sabinene hydrate (**11**) exhibited these spectral properties: $\lambda_{\max}^{\text{CCl}_4}$ 2.80, 2.90, 7.23, 8.46, 9.46, 9.71, 10.03, 10.34, 10.86, and 10.99 μ; nmr signals at τ 8.70 (3 H, HOCCH$_3$), 9.03 (3 H, doublet, J = 7 Hz, CHCH$_3$), 9.10 (3 H, doublet, J = 7.5 Hz, CHCH$_3$), 9.62 [1 H, quartet, J(C-6-*exo* H, C-1 H) = 8.1 Hz, J(C-6-*endo* H, C-6-*exo* H) = 5.0 Hz, C-6-*exo* H], and 9.80 [1 H, triplet, J(C-6-*endo* H, C-1 H) = 5.0 Hz, J(C-6-*endo* H, C-6-*exo* H) = 5.0 Hz, C-6 H (*endo*)].[24,25] Pure *trans* isomer as described by Eastman[18] exhibited spectra identical with those described above. Glpc retention time (125°) of the synthetic **11** was identical with those of a sample obtained from native spearmint and to a sample obtained from Dragoco Chemical Co.

Registry No.—**2**, 13901-85-4; **4**, 1619-28-9; **5**, 15826-78-5; **7**, 15826-79-6; **8**, 15826-80-9; **9**, 513-20-2; **10**, 15826-82-1; **11**, 15826-83-2.

Acknowledgments.—The technical assistance of Mr. Kerry M. Fitzpatrick on part of this work is gratefully acknowledged.

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[23] R. D. Smith and H. E. Simmons, *Org. Syn.*, **41**, 72 (1961).

[24] See W. G. Dauben and W. T. Wipke, *J. Org. Chem.*, **32**, 2976 (1967), for a discussion of nmr spectra of related bicyclic compounds.

[25] IUC nomenclature has been employed, see structure **7**.

[26] G. Ohloff, G. Uhde, A. F. Thomas, and E. sz. Kováts, *Tetrahedron*, **22**, 309 (1966).

The Reactions of Fluoroaromatic Nitriles with Sodium Pentafluorophenolate

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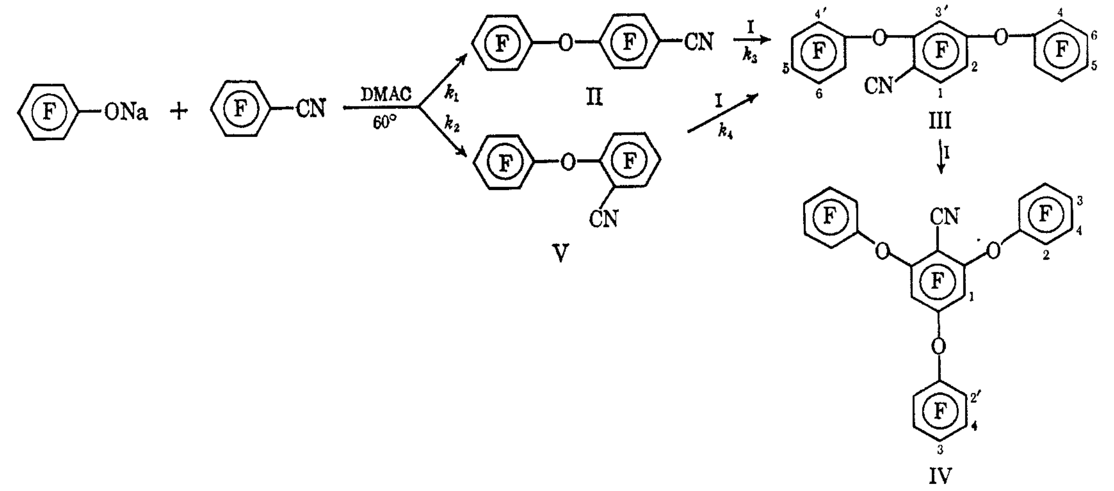
Sodium pentafluorophenolate (I) reacts with a series of substituted pentafluorobenzenes in dimethylacetamide (DMAC) yielding 4-substituted nonafluorodi-

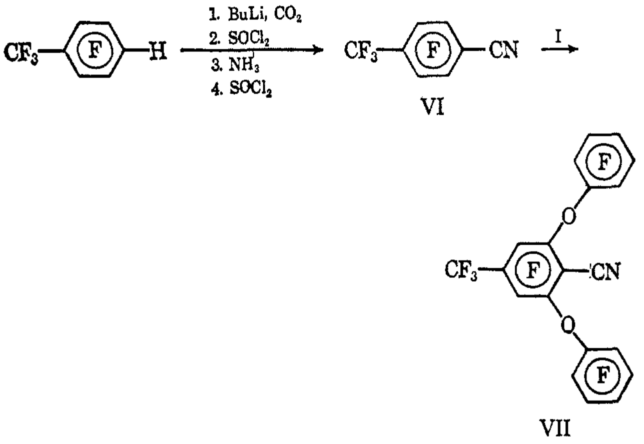


phenyl ethers.[1] In our continuing studies on the synthesis and reactions of perfluorodiphenyl ethers we have observed that I reacts with pentafluorobenzonitrile[2] to yield either mono- and/or polysubstituted products.

4-Cyanononafluorodiphenyl ether (II) was synthesized in an 82% yield through the reaction between I and pentafluorobenzonitrile in an acetone medium (25°). In DMAC as a solvent (70°), an unusual abundance of isomeric and polysubstituted products accompanied the formation of II. When 2.24 equiv of I was allowed to react with 1 equiv of pentafluorobenzonitrile, two polysubstituted products (III and IV) were isolated. All reactions carried out in this study were monitored by vapor phase chromatographic (vpc) analysis. As the reaction proceeded, the concentration of II and another product V (suspected to be the *ortho* isomer) steadily increased and then diminished with further reaction time. Their ratio (II:V, 10:1) was relatively constant during the initial stages of the reaction. However, as the product III began to appear, this ratio became progressively larger implying that V was consumed faster than II. These observations can be rationalized by considering the following scheme where $k_1 > k_2$ and $k_4 > k_3$.

We have shown in our previous study[1] that in a series of monosubstituted pentafluorobenzenes (C_6F_5X, X = H, F, Cl, Br, C_6F_5, CO_2Et, and CF_3) the CF_3 group was the most activating group towards nucleophilic reactions with I. In order to assess the activating influence of a CN group, a competitive experiment was carried out between pentafluorobenzonitrile and octafluorotoluene for I in DMAC (47°). Analysis of the *p*-perfluorodiphenyl ether products in the reaction mixture demonstrated the greater reactivity of pentafluorobenzonitrile [$k(C_6F_5CN)/k(C_6F_5CF_3) = 39$ (*para*)]. From the ratio of V:II in this experiment, *ortho* substitution on pentafluorobenzonitrile was estimated to be as fast as *para* substitution on octafluorotoluene.

In order to demonstrate the facile displacement of the fluorine atoms *ortho* to a CN group, 4-trifluoromethyltetrafluorobenzonitrile (VI) was synthesized from 4-hydroheptafluorotoluene by conventional methods. The reaction of VI with I gave the expected *ortho* disubstituted product VII.



The activating effect of a CN substituent was further demonstrated by the observation that both pentafluorobenzonitrile and compound III were obtained when II was allowed to react with anhydrous sodium fluoride under stringent reaction conditions (DMAC, 110°, 18 hr). This demonstrates the potential reversibility of the reaction between pentafluorobenzonitrile and I. Our recently reported[1] reactions between I and the less reactive substituted pentafluorobenzenes were irreversible under these experimental conditions in agreement with the relative rate data and the reported mechanistic interpretation. Apparently in the reaction between pentafluorobenzonitrile and I (or the reverse reaction, *e.g.*, II and NaF), the CN group can stabilize the rate-determining transition state to the extent that reversibility is realized.

The observations in this study strongly suggest that a CN substituent is a potent activator for *ortho* and *para* nucleophilic substitution reactions on fluorinated aromatic compounds.

Experimental Section

The fluoroaromatics in this work were purchased from Imperial Smelting Corporation Ltd., Avonmouth, England, and were used without further purification. The DMAC was analytical grade and dried over a molecular sieve (Linde Molecular Sieve 5A) prior to use; all other solvents utilized were analytical grade. Boiling points and melting points are uncorrected.

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(1) R. J. De Pasquale and C. Tamborski, *J. Org. Chem.*, **32**, 3163 (1967).

(2) In addition to our study of pentafluorobenzonitrile, recent reports also indicate that a polyfluoroaromatic nitrile undergoes facile *ortho* and *para* nucleophilic substitution reactions. See (a) E. Felstead, H. C. Fielding, and B. J. Wakefield, *J. Chem. Soc. C*, 708 (1966); (b) R. D. Chambers, R. A. Storey, and W. K. R. Musgrave, Fourth International Symposium on Fluorine Chemistry, Estes Park, Colo., July 1967, paper no. 39.

The F^{19} nmr spectra were recorded on a Varian V-4300-2-DP spectrometer at 40 Mcps. Chemical shifts are reported in parts per million (ppm) from external trifluoroacetic acid (TFAA). Acetone was used as the solvent unless otherwise stated. Infrared spectra were run on a Perkin-Elmer Infracord spectrophotometer as KBr pellets or as liquid films. The vapor phase chromatography analysis was done on an F & M Model 500 instrument using a helium flow of 60 cc/min, a 6 ft × 0.25 in. column, 20% Apiezon L on 60–80 mesh Chromosorb W, and programmed from 100–275° (21° per minute) after which it was held at this temperature. The mass spectra were recorded on an AEI MS-9 mass spectrometer.

4-Cyanononafluorodiphenyl Ether (II).—Pentafluorobenzonitrile (20.0 g, 0.104 mol), sodium pentafluorophenolate (10.4 g, 0.0520 mol), and 200 ml of anhydrous acetone were stirred at room temperature under a helium atmosphere. The reaction was followed by periodically withdrawing samples of the reaction mixture and analyzing by vpc. After about 3 days, the reactant (C_6F_5CN) and product peaks remained constant. Less than 2% of side products were present in this crude reaction mixture. The solvent was evaporated and the unreacted pentafluorobenzonitrile was removed by distillation at reduced pressure. The residue was triturated with petroleum ether (30–60°) and filtered to remove 1.7 g of inorganic salts. The filtrate was concentrated and deposited an off-white solid which was recrystallized from methanol–water (40:3) to yield 12.3 g of a white solid, mp 61–62°. Upon further concentration of the mother liquor, 4.8 g of additional solid was obtained. This crude material was dissolved in petroleum ether (30–60°) and eluted from an alumina column with petroleum ether (30–60°). Further recrystallization (methanol–water) yielded 2.8 g of product, mp 59–62° (15.1-g total, 82% yield). A vpc analysis of the combined solids showed less than 1% impurity. The infrared spectrum of II showed a CN band at 4.4 μ. The ^{19}F nmr spectrum was consistent with the assigned structure.

Anal. Calcd for $C_{13}F_9NO$: C, 43.72; F, 47.88; N, 3.92. Found: C, 43.73; F, 47.62; N, 3.95.

Reaction of Pentafluorobenzonitrile with Excess Sodium Pentafluorophenolate.—Pentafluorobenzonitrile (3.27 g, 0.0170 mol) and sodium pentafluorophenolate (7.83 g, 0.0380 mol) were added to DMAC (100 ml) under an atmosphere of nitrogen. The stirred reaction mixture was maintained at 60° for 18 hr, allowed to cool, and filtered to remove the inorganic salts. The filtrate was then added to 300 ml of distilled water, causing a solid to precipitate. The aqueous DMAC solution was decanted; the solid was washed with water and cold methanol. This crude material, 7.9 g, had a melting point range of 130–150°. This solid was then stirred in 80 ml of refluxing hexane and filtered while hot leaving 3.2 g of an insoluble fraction. Recrystallization of this insoluble material from petroleum ether (90–120°) yielded 2.9 g (25%) of a white crystalline solid, mp 184–185°. Structure IV was proposed for this component based on elemental and nmr analysis.

Anal. Calcd for $C_{25}F_{17}O_3N$: C, 43.82; F, 47.14; N, 2.04. Found: C, 43.94; F, 46.85; N, 2.36.

The F^{19} nmr spectrum of IV exhibited a broad singlet at 70.0 ppm (area 2) which on an expanded scale showed five distinct lines with two more (heptet) barely distinguishable. This band was assigned F-1 coupled to F-2 and F-2′. At 74.9 ppm (area 6) was a three-band multiplet (with fine structure) which is believed to be composed of two sets of superimposable doublets, F-2 and F-2′, the former being more deshielded owing to the inductive and anisotropic influences of the cyano group. The remaining absorptions, a distorted triplet (area 3) at 83.4 and a triplet with fine structure (area 6) at 86.4 ppm, were assigned F-3 and F-4, respectively. The experimental coupling constants are $J_{12,12'} \sim 4$; $J_{24} \sim 21$; $J_{34} \sim 21$; and $J_{23,2'3} \sim 3$ cps.

The nmr data indicates that restricted rotation at room temperature appears to be negligible owing to the J_{12} coupling symmetry.

The hexane soluble fraction was concentrated and eluted from a short alumina column with hexane. Concentration of the solvent yielded 3.7 g (41%) of a colorless oil that solidified on standing, mp 70–72° (III).

Anal. Calcd for $C_{19}F_{13}O_2N$: C, 43.78; F, 47.39; N, 2.69. Found: C, 43.89; F, 47.01; N, 2.71.

The F^{19} nmr spectrum of III exhibited a doublet of doublets at 55.6 ppm (area 1) assigned F-1 ($J_{12} \sim 21$; $J_{13} \sim 10$ cps), a doublet of quartets centered at 71.8 ppm (area 1) assigned F-2 ($J_{23,24} \sim 4$ cps), and a broad multiplet (area 1) centered at 76.1 ppm assigned to F-3. The remaining absorptions at 76.9 (area 4), 83.0 (area 2), and 85.8 ppm (area 4) were assigned F-4–F-4′, F-5, and F-6, respectively. Similar with the spectrum of IV, the band at 76.9 ppm consisted of two sets of superimposable doublets.

The infrared spectra of III and IV indicated CN absorptions at 4.44 and 4.49 μ, respectively.

Reaction of 4-Cyanononafluorodiphenyl Ether and Sodium Fluoride.—In an atmosphere of nitrogen, 4-cyanononafluorodiphenyl ether (1.0 g, 2.8 mmol), anhydrous sodium fluoride (0.18 g, 2.8 mmol), and 35 ml of DMAC were heated and stirred at 110° for 18 hr. The reaction mixture was allowed to cool and added to 100 ml of distilled water. The resulting mixture was extracted with three 30-ml portions of methylene chloride. The combined organic extracts were washed three times with 30-ml portions of water, dried over magnesium sulfate, and concentrated, yielding 0.9 g of a solid residue. A vpc analysis of this residue showed that the mixture consisted of three components in the ratio 1:50:2. The components were identified as pentafluorobenzonitrile, 4-cyanononafluorodiphenyl ether (II), and 2,4-bis(pentafluorophenoxy)-3,5,6-trifluorobenzonitrile (III), respectively.

4-Trifluoromethyltetrafluorobenzonitrile (VI).—4-Trifluoromethyltetrafluorobenzoic acid[3] (18.0 g, 0.0680 mol) was added to thionyl chloride (72.8 g, 0.560 mol) containing 0.3 g of dimethylformamide. The solution was heated at reflux temperature for 17 hr. During the first 5 hr, gas evolution was noted. The excess thionyl chloride was removed (water aspirator) and the remaining residue was distilled to yield 16.0 g (84%) of 4-trifluoromethyltetrafluorobenzoyl chloride, bp 70–72° (12 mm). The infrared spectrum of the acid chloride exhibited a C=O band at 5.70 μ.

The acid chloride was added dropwise to a stirred solution of 15 *N* ammonium hydroxide (7.0 g) in 40 ml of THF. During the addition, the temperature of the reaction mixture was maintained at −10 to 0°. At the completion of the reaction, the white precipitate which formed was filtered (NH_4Cl). The filtrate was concentrated yielding 14.5 g (98%) of the desired amide, mp 147–149°. The infrared spectrum of the amide exhibited an NH band at 2.95 and 3.15 and C=O band at 6.00 μ. The amide was used subsequently without further purification.

The amide was converted into 4-trifluoromethyltetrafluorobenzonitrile VI by the procedure described by Marvel and Martin.[4] The desired product VI, mp 31–32° (37%), was obtained and characterized by high resolution mass spectrometry and F^{19} nmr analysis.

Anal. Calcd for C_8F_7N: mol wt, 242.9919. Found: mol wt, 242.9928.

The F^{19} nmr spectrum exhibited a triplet at −20 ppm (J = 22 cps), one-half of an AA′XX′ pattern at +54.5 and a complicated multiplet at 61.4 ppm with relative areas of 3:2:2, respectively.

2,6-Bis(pentafluorophenoxy)-4-trifluoromethyldifluorobenzonitrile VII.—Sodium pentafluorophenolate (340 mg, 1.64 mmol) was added to 4-trifluoromethyltetrafluorobenzonitrile dissolved in 5 ml of DMAC. The reaction, carried out under an atmosphere of nitrogen, was stirred and heated at 50° for 24 hr. The solvent was distilled under vacuum (water aspirator) and the remaining residue (0.55 g) was dissolved in benzene. The benzene solution was placed on an alumina column and eluted with a benzene–petroleum ether (30–60°) solution (1:1). In this manner a yellow oil (0.35 g) was obtained which solidified on standing, mp 78–82°. Recrystallization from hexane afforded 0.25 g (50%) of the product VII, mp 89–91°.

The product VII was characterized by high resolution mass spectrometry and F^{19} nmr and infrared spectral analysis.

Anal. Calcd for $C_{20}F_{15}NO_2$: mol wt, 570.9681; Found: mol wt, 570.9690.

The F^{19} nmr spectrum exhibited typical pentafluorophenoxy absorptions at 79.1, 82.8, and 85.8 (relative area 4:2:4), a triplet at −19.8 (J = 24 cps, relative area 3), and a quartet of quintets at +53.4 ppm (J = 1 cps, relative area 2).

The infrared spectrum of both compound VI and VII exhibited a weak CN band at 4.45 μ.

Registry No.—I, 2263-53-8; II, 15895-67-7; III, 15963-72-1; IV, 16031-36-0; VI, 15895-68-8; VII, 16065-60-4.

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[3] C. Tamborski and E. J. Soloski, *J. Org. Chem.*, **31**, 746 (1966).

[4] C. S. Marvel and M. M. Martin, *J. Amer. Chem. Soc.*, **80**, 6603 (1958).

Acknowledgments.—The authors wish to thank J. V. Pustinger, Jr., and J. Strobel of Monsanto Research Corp. for obtaining the F^{19} nmr spectra and J. R. Boal of Mellon Institute for obtaining the mass spectra reported in this work.

The Degradation of (−)-4-Methylisopulegone to (+)-2-Isopropyl-2-methylsuccinic Acid[1]

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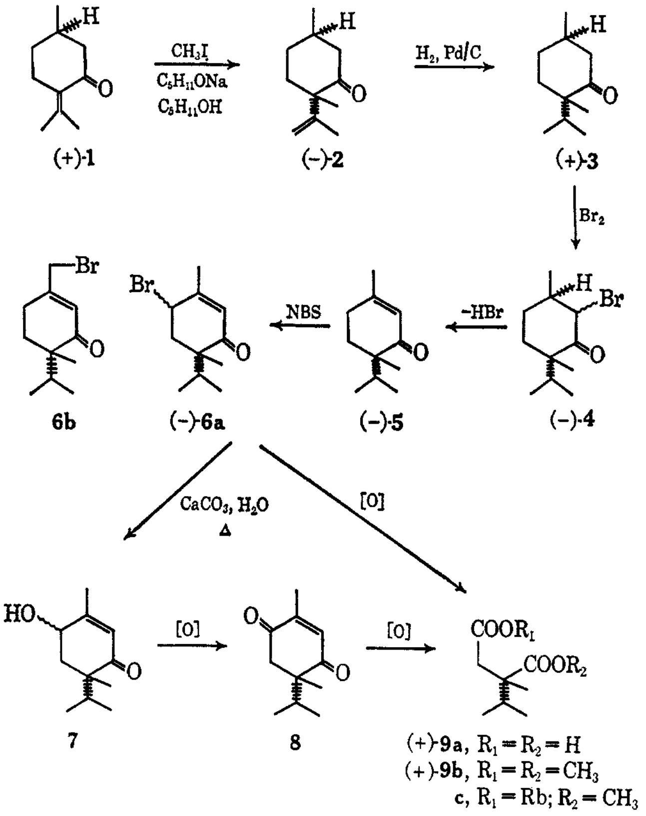
The conversion of (−)-4-methylisopulegone [(−)-4-methyl-*p*-menth-8(9)en-3-one)] (**2**) into (+)-2-isopropyl-2-methylsuccinic acid (**9a**) and the structures of the intermediate products are reported. The absolute configuration of **2** has been unequivocally established by X-ray crystallography of the rubidium salt of the half-methyl ester of (+)-2-isopropyl-2-methylsuccinic acid (**9c**). The acid **9a** is important since it is a degradation product of several terpenes,[3] including (+)-camphor,[4] (+)-thujone,[5] and (+)-sabinene,[6] and has been used to establish the absolute configuration of these and related molecules. We had previously arrived at an incorrect assignment of the absolute configuration of **2** through a quasi-racemate study involving (+)-2-isopropyl-2-methylglutaric acid (**11a**) and (+)-2-isopropylglutaric acid. Since quasi-racemate formation was observed between these acids, we had concluded that the isopropyl groups of these two molecules should have opposite configurations.[7] The paucity of material at that time prevented degradation to 2-isopropyl-2-methylsuccinic acid of known absolute configuration.[8] We have devised and now report a successful degradation of **2** which provides enough **9a** for complete characterization and optical rotation studies.

The reaction sequence used in the degradation is shown in Scheme I, which includes the alkylation of (+)-pulegone (**1**) to (−)-**2**. The latter was isolated and purified as previously reported.[7a] The structure of **2** was confirmed by ir, mass, nmr, and uv spectral data. Catalytic hydrogenation of **2** afforded the expected (+)-4-methyl-*p*-menth-3-one (**3**). Its conversion into the unsaturated ketone **5** *via* the crystalline bromo ketone **4** was also accomplished.[7a]

SCHEME I



All previous attempts at degrading the unsaturated ketone **5** to **9a** failed. We therefore sought a degradation route in which we could activate or substitute C-4 of the unsaturated ketone **5** in such a way that 2-isopropyl-2-methylsuccinic acid could be obtained. Allylic bromination of **5** with N-bromosuccinimide in carbon tetrachloride yielded an unsaturated bromo ketone. This bromination product might be **6a** or **b**. The structure **6a** was apparent from the nmr spectrum, which shows a sharp singlet at τ 8.15 (3 H) due to a vinylic methyl group, whereas the parent ketone **5** shows this methyl signal at 8.10 (3 H). The shift is attributed to the inductive effect exerted by the bromide substituent. The absence of absorption due to allylic methylene protons in the τ 7.5–8.0 region and the survival of the methyl group during bromination provide convincing evidence that structure **6a** is correct. Additional evidence for the formation of a monobromination product is gained from the bromine analysis. Oxidation of **6a** with alkaline potassium permanganage gave **9a**, mp 128–130°, $[\alpha]^{24}\text{D}$ +15° (*c* 0.8, C_2H_5OH). A mixture of **9a** obtained from the degradation with an authentic sample of (+)-**9a** showed no depression in melting point.[9] The infrared spectra of these samples were identical, and the mass fragmentation patterns of **9a** and **9b** confirm the structure assignment to **9a**.

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(1) (a) This study was initiated before the X-ray crystallography studies were published.[1b] (b) M. R. Cox, H. P. Koch, W. B. Whalley, M. B. Hursthouse, and D. Rogers, *Chem. Commun.*, 212 (1967).

(2) (a) M. V. Kulkarni, Ph.D. Thesis, Oklahoma State University, Stillwater, Okla., May 1967. (b) Address correspondence and reprint requests to this author.

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