was then cooled, acidified and extracted with ether. Concentration of the ether solution produced a solid product, m.p. 133–140°. Recrystallization from dimethylformamide-water (1:1) and then from ethanol-water (1:1) yielded the pure amic acid IIIa.

α-Ethyl-α-phenylcarbamylmethyl-α′-mercaptobutyric acid (IIIb). Ethylphenylmercaptoacetamide (3.0 g., 0.015 mole) was dissolved in 32 cc. (0.08 mole) of 10% sodium hydroxide solution. α-Bromobutyric acid (2.7 g., 0.016 mole) was added dropwise to the stirred solution. After stirring for 1 hr. the mixture was cooled and acidified. The oil which formed was taken up in ether and the ether solution was extracted with sodium bicarbonate. The bicarbonate layer was cooled, acidified and extracted with ether. Concentration of the ether layer produced a solid, m.p. 142–144°. Repeated recrystallization from dimethylformamide-water (1:1) and then from ethanol-water (1:1) produced the pure amic acid IIIb.

α-Ethyl-α-phenylcarbamylmethyl-α′-mercaptocaproic acids (IIIc-A and IIIc-B). *From* IVf-A. This diamide (1.0 g., 0.0027 mol.) was dissolved in 3 cc. of 5% sodium hydroxide solution (0.0037 mol.) and heated to 70° for 1 hr. Upon cooling and acidifying a gunky white precipitate formed which hardened on standing, m.p. 140–150°. Recrystallization from isopropyl alcohol produced 0.8 g. of pure IIIc-A. By working up the filtrates and recrystallizing from ethanol a small amount of impure IIIc-B was obtained.

From IVf-B. This diamide was treated similarly. The solid which precipitated was filtered and washed with water. It was then recrystallized from isopropyl alcohol; first crop, m.p. 157–158° (IIIc-A); second crop, m.p. 135–142° (mostly IIIc-B).

From the thiomorpholinedione Ij (Table II). This compound (1.0 g., 0.0034 mole) was dissolved in 10 cc. of 1.5% sodium hydroxide solution (0.0037 mol.). The mixture was allowed to stand at room temperature for 24 hr. All of the solid had dissolved after standing for 16 hr. The solution was cooled in ice and acidified. The precipitate was collected, m.p. 145–148°. Recrystallization from isopropyl alcohol-water (5:1) gave pure IIIc-A. A second crop from the filtrate of the first recrystallization was obtained, m.p. 137–140°. Repeated recrystallization of this from ethanol-water (5:1) gave pure IIIc-B. The melting point of a mixture of the two isomers was lower (*ca.* 135°).

2,2,6-Trisubstituted-3,5-thiomorpholinediones. From an amic acid type III. The amic acid IIIb (5.6 g., 0.020 mol.) was heated at 150–155° for 1 hr. while being evacuated. Water was evolved vigorously at first. Upon cooling an oily solid residue remained which was triturated with sodium bicarbonate solution leaving a solid, m.p. 67–70°. Recrystallization from an isopropyl alcohol–water mixture produced pure 2,6-diethyl-2-phenyl-3,5-thiomorpholinedione.

From an amic acid type II. In a typical example a mixture of IIg-A and IIg-B (8.1 g., 0.026 mol.) was placed in a distilling flask and heated at 180–190° for 90 min. under a vacuum. The oil which remained on cooling was taken up in isopropyl alcohol and cooled. Water was added until the solution became cloudy. The crystalline product was collected and recrystallized from isopropyl alcohol producing pure 6-*n*-butyl-2-ethyl-2-phenyl-3,5-thiomorpholinedione.

From the diamide. In a typical example IVa (7.6 g., 0.033 mol.) was dissolved in 20 cc. of concentrated hydrochloric acid and refluxed for 1 hr. Upon cooling, white needles formed. Recrystallization from ethanol gave pure 2,2,6-triethyl-3,5-thiomorpholinedione.

From the racemic diamide IVf-A. This diamide (7.6 g., 0.025 mol.) was dissolved in 20 cc. of hydrochloric acid (S.G. 1.18) and the solution was refluxed for 1 hr. When cooled an oil separated which would not crystallize. Distillation of the oil under diminished pressure gave a viscous colorless oil which solidified on standing. Recrystallization from isopropyl alcohol produced pure 6-*n*-butyl-2-ethyl-2-phenyl-3,5-thiomorpholinedione.

From the racemic diamide IVf-B. This diamide (1.5 g., 0.0049 mol.) was dissolved in 5 cc. of hydrochloric acid (S.G. 1.18) and the solution was refluxed for 75 min. Upon gradual cooling, finally in ice, a solid formed. One crystallization of this from isopropyl alcohol gave the identical 6-*n*-butyl-2-ethyl-2-phenyl-3,5-thiomorpholinedione.

Acknowledgments. We are grateful to the Laboratories of Merck, Sharp and Dohme, West Point, Pa., for financial aid to James S. Elmslie and for the analytical determinations. We received also a generous gift of ethylisobutylacetic acid from Eastman Chemical Products, Inc., Kingsport, Tenn.

NEWARK, DEL.

[CONTRIBUTION FROM THE MORLEY CHEMICAL LABORATORY, WESTERN RESERVE UNIVERSITY]

Reactions of Perfluoroalkyl Isocyanates with Amines

RALPH L. DANNLEY, DONALD YAMASHIRO,[1] AND ROBERT G. TABORSKY[2]

Received April 13, 1959

Perfluoroalkyl isocyanates react with stoichiometric quantities of primary amines at low temperatures to form perfluoroalkyl ureas. These ureas readily undergo replacement of the alpha fluorine atoms to yield perfluoroacyl ureas. Solvolysis of the ureides to remove the perfluoroacyl group can be accomplished by refluxing with excess amine. The reaction of the perfluoroalkyl isocyanates with secondary amines could not be controlled and produced perfluoroacyl amidines.

It has been reported[3] that perfluoroalkyl isocyanates react abnormally with amines to yield compounds of undetermined structure instead of the expected ureas. These isocyanates also react abnormally with alcohols but by observing proper

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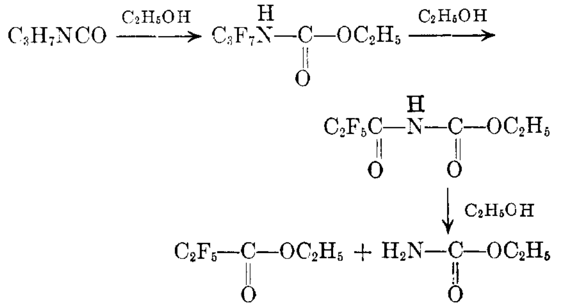
[1] From the thesis to be submitted by Donald Yamashiro to the Graduate School of Western Reserve University in partial fulfillment of the requirements for the doctor's degree. Presented at the Chicago meeting of the American Chemical Society, September 1958.

[2] Present address, Roswell Park Memorial Institute, Buffalo, N.Y.

[3] A. Ahlbrecht, D. Husted, T. Reid, and O. Smith, Contribution No. 34 of Central Research Department, Minnesota Mining and Manufacturing Co., St. Paul, Minn., "Chemistry of Perfluoro Acids and Their Derivatives. IV. Fluoroalkyl Isocyanates."

precautions[4] the expected urethans can be obtained in excellent yield. The present investigation was initiated in expectation that by observing similar precautions, the addition of amines to these isocyanates could be controlled to yield ureas.

It has been shown[4] that perfluoroalkyl isocyanates react normally with stoichiometric quantities of alcohol at low temperatures. With excess alcohol the alpha fluorine atoms of the urethan are replaced to form perfluoroacyl urethans. By refluxing the perfluoroacyl urethans with alcohol, further alcoholysis occurs to give a simple carbamate and an ester. This sequence is represented below:



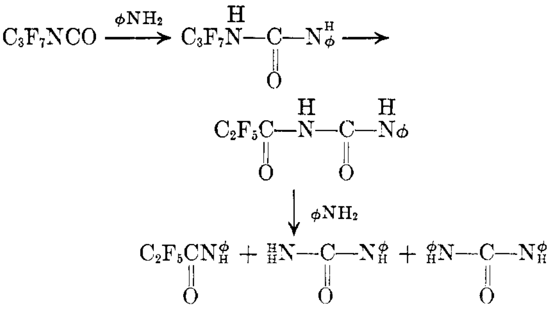
$$\mathrm{C_3H_7NCO} \xrightarrow{\mathrm{C_2H_5OH}} \mathrm{C_3F_7}\overset{\mathrm{H}}{\mathrm{N}}\text{—}\underset{\underset{\mathrm{O}}{\|}}{\mathrm{C}}\text{—}\mathrm{OC_2H_5} \xrightarrow{\mathrm{C_2H_5OH}} \mathrm{C_2F_5}\underset{\underset{\mathrm{O}}{\|}}{\mathrm{C}}\text{—}\overset{\mathrm{H}}{\mathrm{N}}\text{—}\underset{\underset{\mathrm{O}}{\|}}{\mathrm{C}}\text{—}\mathrm{OC_2H_5} \xrightarrow{\mathrm{C_2H_5OH}} \mathrm{C_2F_5}\text{—}\underset{\underset{\mathrm{O}}{\|}}{\mathrm{C}}\text{—}\mathrm{OC_2H_5} + \mathrm{H_2N}\text{—}\underset{\underset{\mathrm{O}}{\|}}{\mathrm{C}}\text{—}\mathrm{OC_2H_5} \tag{1}$$

In the present work it has been found that treatment of the perfluoroalkyl isocyanates with stoichiometric quantities of primary amines at low temperatures gives the corresponding ureas in yields of 27 to 86%. These ureas not only hydrolyze with great ease but in addition undergo appreciable decomposition at room temperature in a period of a few days. Although careful recrystallization from chloroform gives samples of sharp melting point, sufficient decomposition occurs during shipping to a commercial analytical laboratory to result in C, H, and F analyses of limited accuracy. Kjeldahl nitrogen determinations performed on freshly prepared samples provided analytical figures which checked properly with theoretical values.

The ureas obtained from aromatic amines are the most stable. This is to be expected, for the ureas on standing give an odor of hydrogen fluoride and etch the glass containers. This loss of hydrogen fluoride would certainly be accelerated by the presence of residues of the amines of greater basicity.

The decomposition of the ureas on standing leads partially to the formation of perfluoroacyl ureas. In the initial investigation[3] of the reaction of perfluoroalkyl isocyanates with primary amines, the products of undetermined structure were probably mixtures of the expected ureas and the corresponding perfluoroacyl derivatives. The pure perfluoroacyl compounds are very stable and can be obtained in essentially quantitative yield by heating the ureas with aqueous acetone.

The perfluoroacyl ureas undergo solvolysis if refluxed with excess amine. This reaction and those already discussed are represented below.



$$\mathrm{C_3F_7NCO} \xrightarrow{\phi\mathrm{NH_2}} \mathrm{C_3F_7}\mathrm{N}\text{—}\overset{\mathrm{H}}{\underset{\underset{\mathrm{O}}{\|}}{\mathrm{C}}}\text{—}\mathrm{N}^{\mathrm{H}}_{\phi} \longrightarrow \mathrm{C_2F_5}\underset{\underset{\mathrm{O}}{\|}}{\mathrm{C}}\text{—}\overset{\mathrm{H}}{\mathrm{N}}\text{—}\underset{\underset{\mathrm{O}}{\|}}{\mathrm{C}}\text{—}\overset{\mathrm{H}}{\mathrm{N}}\phi \xrightarrow{\phi\mathrm{NH_2}} \mathrm{C_2F_5}\underset{\underset{\mathrm{O}}{\|}}{\mathrm{C}}\mathrm{N}^{\phi}_{\mathrm{H}} + {}^{\mathrm{H}}_{\mathrm{H}}\mathrm{N}\text{—}\underset{\underset{\mathrm{O}}{\|}}{\mathrm{C}}\text{—}\mathrm{N}^{\phi}_{\mathrm{H}} + {}^{\phi}_{\mathrm{H}}\mathrm{N}\text{—}\underset{\underset{\mathrm{O}}{\|}}{\mathrm{C}}\text{—}\mathrm{N}^{\phi}_{\mathrm{H}} \tag{2}$$

This series essentially parallels the reactions given in Equation 1. The initial reactions of the perfluoroalkyl isocyanates with both alcohols and primary amines are normal but are complicated by con-

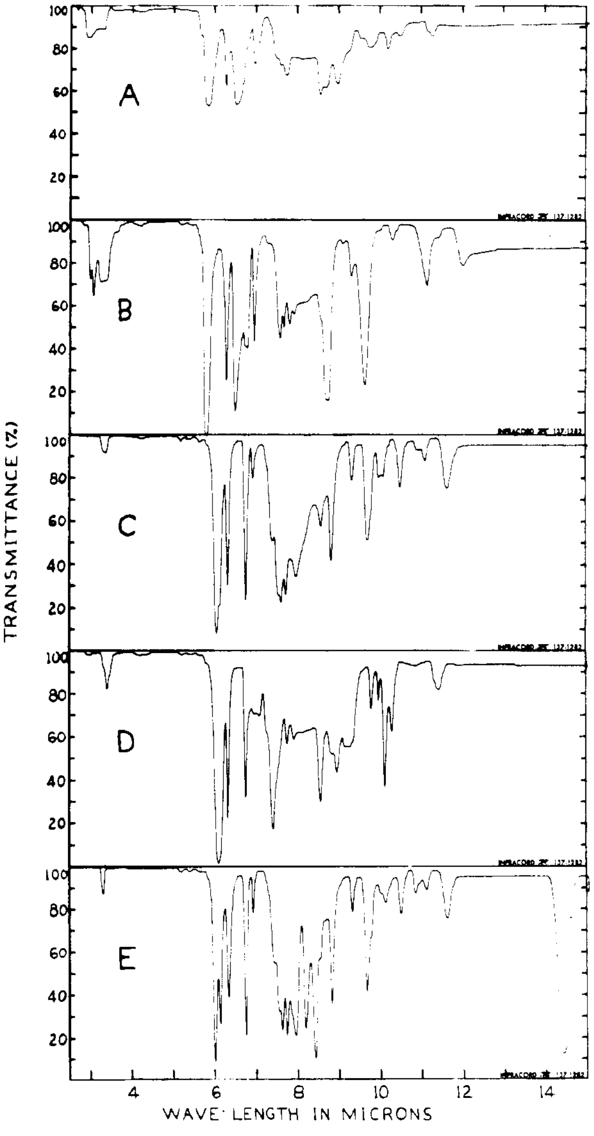


Fig. 1. Infrared spectra: A, *N*-*n*-perfluoropropyl-*N′*-phenylurea, 0.5% in chloroform; B, *N*-perfluoropropionyl-*N′*-phenylurea, 0.91% in chloroform; C, *N*,*N*-diphenyl-*N′*,*N′*-diphenylcarbamylperfluoropropionamidine, 0.94% in chloroform; D, *N*,*N*-methylphenyl-*N′*,*N′*-methylphenylcarbamylperfluoropropionamidine, 0.94% in chloroform; E, *N*,*N*-diphenyl-*N′*,*N′*-diphenylcarbamylperfluoropropionamidine, 0.82% in carbon tetrachloride

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[4] R. L. Dannley and M. Lukin, *J. Org. Chem.*, 21, 1036 (1956).

TABLE I

DESCRIPTIONS OF PRODUCTS

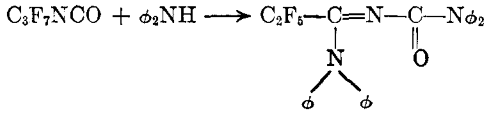
Product	Yield, %	M.P.[f]	Analysis C Calcd.	C Found	H Calcd.	H Found	F Calcd.	F Found	N Calcd.	N Found
N-*n*-perfluoropropyl-*N*′-benzylurea[a]	51[d]	111–112[g]	41.52	42.16	2.85	2.60	41.8	38.5	8.81	8.87[h]
N-*n*-perfluoropropyl-*N*′-*p*-chlorophenylurea[b]	86[d]	122–123[g]	35.47	35.58	1.79	1.63	39.3	35.5	8.27	8.30[h]
N-*n*-perfluoropropyl-*N*′-*n*-butylurea	27[d]	84–84.5[g]	33.81	34.75	3.90	4.09	46.8	46.0	9.86	9.85[h]
N-*n*-perfluoroheptyl-*N*′-*p*-chlorophenylurea	52	120–123[g]							5.21	5.18[h]
N-perfluoropropionyl-*N*′-benzylurea	...	157.5–158	44.60	44.80	3.06	3.08			9.46	9.47[h]
N-perfluoropropionyl-*N*′-*p*-chlorophenylurea	92	157–158	37.93	37.98	1.91	1.74			8.85	8.87
N-perfluoropropionyl-*N*′-*n*-butylurea	93	97.5–98	36.64	36.79	4.19	4.21				
N-*n*-perfluoroheptanoyl-*N*′-*p*-chlorophenylurea	88	142–143							5.42	5.41
N,*N*-diphenyl-*N*′-*N*′-diphenylcarbamylperfluoropropionamidine[c]	54[e]	167.7–168.3	66.01	66.13	3.96	4.04			8.25	8.40

[a] Run at −80°. [b] Run in toluene instead of ether. [c] Reaction mixture heated 5 hr. at 130° in a sealed tube after initial period at room temperature. Mol. wt. calcd. for $C_{28}H_{20}F_5N_3O$, 509. Found, 477. [d] Reaction mixture evaporated to $^1/_5$ its volume and then diluted with 10 volumes of petroleum ether (Skelly B) to precipitate the product. [e] This yield calculated on the basis of two moles of amine needed for each mole of isocyanate consumed. The diphenylamine is therefore the reagent used in limited quantity. [f] All m.p.s are uncorrected. [g] All of these compounds melt with decomposition and evolution of a gas. Recrystallized from ether–petroleum ether. [h] Kjeldahl nitrogen determinations on freshly prepared samples.

secutive reactions involving the labile alpha fluorine atoms.

The last step in the sequence of reactions with aniline is unexpected in that both phenylurea and *sym*-diphenylurea are found. The diphenylurea is probably not a primary product but results from the reaction of excess aniline with phenylurea. This conclusion is substantiated by the absence of perfluoropropionamide which should be present if the diphenylurea is a primary product of solvolysis. This is not a rigid proof of the mechanism, however, for perfluoropropionamide could have been originally present but later converted to the anilide by reaction with excess amine.

The reaction of secondary amines with the isocyanates could not be controlled to form ureas. The only products isolated were amidines produced from the initial urea by a replacement of one alpha fluorine atom by an amino group and the loss of a molecule of hydrogen fluoride.



$$C_3F_7NCO + \phi_2NH \longrightarrow C_2F_5{-}\underset{\underset{\phi\ \ \phi}{N}}{\overset{}{C}}{=}N{-}\underset{O}{\overset{}{C}}{-}N\phi_2$$

A similar solvolysis has been reported[5] to occur when these perfluoroalkyl isocyanates are treated with ammonia. Amidines of similar structure have been obtained from polyfluoro olefins and amines.[6]

The structures of the amidines were substantiated by infrared spectra in addition to analyses and molecular weights. A strong amide peak (N–H stretch) found in every spectrum of a perfluoroalkyl or a perfluoroacyl urea is absent in the amidines. Also, a strong sharp peak at 5.9μ for the urea derivatives is shifted and broadened to 6.05–6.2μ for the amidines. The shift is due partially to the presence of the dialkyl nitrogen structure in place of the monoalkyl type. The broadening and extension to 6.2μ are due to a strong C═N stretch peak at 6.15μ. This 6.15μ absorption can be obtained as a completely independent and sharp peak in dilute solutions of *N*,*N*-diphenyl-*N*′,*N*′-diphenylcarbamylperfluoropropionamidine in carbon tetrachloride. The infrared spectra of these compounds together with those of a representative urea and acyl urea are given in Fig. 1.

EXPERIMENTAL

N-n-Perfluoropropyl-N′-phenylurea. A well stirred solution of 10 g. (0.047 mol.) of *n*-perfluoropropyl isocyanate in 20 ml. of anhydrous ether was cooled to 0° during the slow addition of 4.4 g. (0.047 mol.) of aniline (distilled from zinc). Stirring was continued for 2 hr. at 0° and the solution evaporated under reduced pressure to give 11.0 g. (80% yield) of crude product, m.p. 109° with decomposition. Recrystallization from chloroform gave an analytical sample of *N*-*n*-perfluoropropyl-*N*′-phenylurea, m.p. 111° with decomposition.

Anal. Calcd. for $C_{10}H_7F_7N_2O$: C, 39.48; H, 2.32. Found: C, 39.42; H, 2.61.

This material slowly decomposed at room temperature, and recrystallization from chloroform after 4 weeks gave

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(5) A. Ahlbrecht and D. Husted, U. S. Patent 2,617,817.

(6) R. L. Pruett, J. T. Barr, K. E. Rapp, C. T. Bahner, J. D. Gibson, and R. H. Lafferty, *J. Am. Chem. Soc.*, **72**, 3646 (1950).

only N-perfluoropropionyl-N'-phenylurea, m.p. 143–145° (see below for proof of structure).

Hydrolysis of N-n-perfluoropropyl-N'-phenylurea to the acyl ureide. Refluxing an acetone solution of a small sample of N-n-perfluoropropyl-N'-phenylurea for a few minutes and addition of water produced a white precipitate. Recrystallization from acetone-water gave N-perfluoropropionyl-N'-phenylurea, m.p. 145.5–146°.

Anal. Calcd. for $C_{10}H_7F_5N_2O_2$: C, 42.56; H, 2.50; N, 9.93. Found: C, 42.67; H, 2.39; N, 9.81.

N-Perfluoropropionyl-N'-phenylurea. The structure of this compound was proved by an independent synthesis.[7] A solution of 2.01 g. (0.0123 mol.) of perfluoropropionamide and 1.45 g. (0.0122 mol.) of phenyl isocyanate in 10 ml. of dry toluene was refluxed for 48 hr. After storing at 0° for 3 days, the precipitate which formed was isolated and recrystallized from acetone-water to give 1.50 g. (43% yield) of N-perfluoropropionyl-N'-phenylurea, m.p. 144.5–146.5. A mixed m.p. with the hydrolysis product of N-n-perfluoropropyl-N'-phenylurea showed no depression.

Reaction of N-perfluoropropionyl-N'-phenylurea with excess aniline. A mixture of 1.00 g. (.00354 mol.) of the N-perfluoropropionyl-N'-phenylurea and 3.25 ml. (0.0357 mol.) of aniline was heated to 90° for 20 hr., cooled, and then acidified with 30 ml. of 10% hydrochloric acid. The aqueous acid solution was extracted with four 50-ml. portions of ether. The combined ether extracts, dried over magnesium sulfate, were evaporated to dryness and the solids treated with 30 ml. of boiling ligroin. Filtration of the hot solution gave an insoluble residue from which by fractional crystallization from ethanol-water was isolated 0.30 g. of *sym*-diphenylurea (m.p. 234–235°) and 0.08 g. of phenylurea (m.p. 137–141°). The identities were established through further purification and mixed m.p. with authentic samples.

Evaporation of the ligroin solution to 15 ml., chilling to −60°, and filtering gave 0.56 g. of white crystals, m.p. 95–97°. Recrystallization from ethanol-water gave pure perfluoropropionanilide, m.p. 97.5–98.5°.

Anal. Calcd. for $C_9H_6F_5NO$: C, 45.20; H, 2.53; N, 5.86; mol. wt. 239.16. Found: C, 45.25; H, 2.53; N, 6.10; mol. wt. 247.

The identity was confirmed by a mixed m.p. with an authentic sample of perfluoropropionanilide prepared by passing perfluoropropionyl chloride into a solution of aniline in ether.

Reactions of benzylamine with perfluoropropyl isocyanate. To prove the generality of the above sequence of reactions, the entire series through the ultimate solvolysis to benzyl urea was successfully repeated using benzyl amine.

N,N-Methylphenyl-N',N'-methylphenylcarbamylperfluoropropionamidine. Over a period of 40 min., 3.44 ml. (0.0318 mol.) of methylaniline in 30 ml. of dry ether was slowly added at −60° to 6.7 g. (0.0317 mol.) of perfluoropropyl isocyanate in 30 ml. of dry ether. After an additional 1.5 hr. at −60° and 6 hr. at room temperature, the mixture was stored at −30° for 2 weeks. Vacuum evaporation of the ether left an oily residue which was dissolved in 10 ml. of ligroin and 10 ml. of benzene. Vacuum evaporation of the mixture gave three successive crops of crystals, 4.27 g. (70%), m.p. 68.5–70°. Recrystallization from acetone-water and decolorizing with Norit gave white, crystalline N,N-methylphenyl-N',N'-methylphenylcarbamylperfluoropropionamidine, m.p. 71–72°.

Anal. Calcd. for $C_{18}H_{16}F_5N_3O$: C, 56.10; H, 4.19; N, 10.90; mol. wt., 385. Found: C, 56.27; H, 4.29; N, 11.09; mol. wt., 378; (m.p. depression of benzene).

CLEVELAND, OHIO

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[7] P. F. Wiley, *J. Am. Chem. Soc.*, **71**, 1310 (1949).

[CONTRIBUTION FROM DEPARTMENT OF CHEMISTRY, OHIO STATE UNIVERSITY]

Fluorinated Paraffins

R. H. GROTH[1]

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Paraffins with fluorinated clusters at one end, both ends, or in the middle of the chain have been synthesized from perfluorinated acids and their derivatives.

Many propanes and butanes are known[2] which have clustered fluorine atoms as in $CF_3C_3H_7$, $CF_3CH_2CH_2CF_3$, or $CF_3CF_2CF_2CH_3$. One pentane, $CF_3C_4H_9$, has been reported,[3] but no longer paraffin. The present paper shows the synthesis of hexanes and heptanes with their fluorinated groups diversely spaced, namely $C_3F_7C_3H_7$, $C_2H_5C_2F_4C_2H_5$, $C_3F_7CH_2CH(CH_3)_2$, and $CF_3(CH_2)_4CF_3$. They were prepared for an examination of their physical properties and the character of their carbon-hydrogen bond to be reported separately.[4]

The syntheses of these hexanes and heptanes involved basically a reduction starting with readily available perfluorinated acids. Particularly advantageous would be a reduction to a carbonyl function from an acid or derivative by use of Grignard or similar reagent. The carbonyl could be further reduced to the desired paraffin.

Esters of perfluorinated acids were unsuitable as they were known to give alcohols exclusively on treatment with $LiAlH_4$ or Grignards.[5] Anhydrides of unfluorinated acids yielded some carbonyl compounds at low temperatures[6] which was explained

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[1] Present address: Department of Chemistry, University of Hartford, Hartford, Conn.

[2] A. L. Henne, J. W. Shepard, and E. J. Young, *J. Am. Chem. Soc.*, **72**, 3577 (1950).

[3] R. N. Haszeldine, *J. Chem. Soc.*, 2856 (1949).

[4] This phase of the work will be published by A. L. Henne. It has been orally presented by A. L. H. at the International Symposium on Fluorine Chemistry, at Birmingham, England in July 1959.

[5] E. Gryskiewicz-Trochimowski, *Rec. trav. chim.*, **66**, 427 (1947).

[6] M. S. Newman and Fr. O'Leary, *J. Am. Chem. Soc.*, **68**, 258 (1946).