Synthesis of Polyfluorinated Heterocycles by Indirect Fluorination with Silver Fluorides. III. Fluoropiperideines, Fluoropyrrolines, and Fluoropyrrolenine[1,2]

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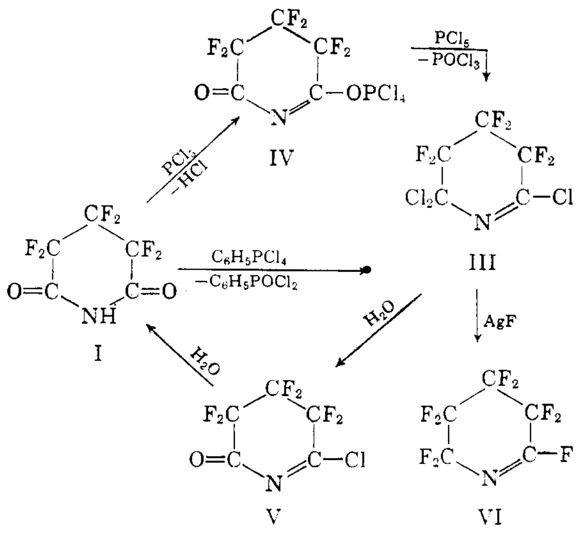
Perfluoro-1-piperideine and perfluoro-1-pyrroline were synthesized from hexafluoroglutarimide and tetrafluorosuccinimide, respectively, by chlorination with phosphorus pentachloride or phenylphosphorus tetrachloride and subsequent exchange of the α-bonded chlorine atoms of the chlorination products, 2,6,6-trichloro-3,3,4,4,5,5-hexafluoro-1-piperideine and 2,5,5-trichloro-3,3,4,4-tetrafluoro-1-pyrroline, with fluorine by means of silver fluorides. The chlorine atoms of the intermediates proved to be very reactive, *e.g.*, upon reaction with ammonia and with primary amines fluorinated cyclic imidines were obtained. Fluorination of pentachloropyrrolenine with silver fluoride yielded 3,4-dichloro-2,2,5-trifluoropyrrolenine.

Very few perfluorinated heterocyclic compounds with one nitrogen atom in the nucleus are reported in the literature. Perfluoropiperidine has been obtained upon fluorination of pyridine with cobalt trifluoride,[3] fluorine and gold-plated copper turnings,[3] or hydrogen fluoride,[4] and heptadecafluorodecahydroquinoline has been prepared from quinoline by means of cobalt trifluoride.[5] Recently, pentafluoropyridine has been reported for the first time.[6]

Our studies on other heterocyclic systems[7,8] showed that halogen atoms in the position alpha to hetero-ring atoms are remarkably reactive and can be easily exchanged by fluorine by means of inorganic fluorinating agents such as the silver fluorides. Therefore, for the purpose of extending our investigations to the class of perfluorinated five- and six-membered ring systems with one nitrogen atom in the nucleus, available starting materials for the synthesis of such compounds were hexafluoroglutarimide (I) and tetrafluorosuccinimide (II) which, upon chlorination, should form products with the chlorine atoms in the reactive α-positions. Both imides, I and II, are easily accessible from the corresponding diamides on treatment with sulfuric acid.[9]

Hexafluoroglutarimide (I) was chlorinated by heating with phosphorus pentachloride to give 2,2,6-trichloro-3,3,4,4,5,5-hexafluoro-1-piperideine (III). Apparently, I reacted in its tautomeric form, with the first reaction being the esterification of the hydroxy group, to result in the tetrachlorophosphorane (IV) which, upon heating, eliminated phosphoryl chloride. This mechanism was supported by the isolation of the intermediate IV when heating was limited to a short period.

2,2,6 - Trichloro - 3,3,4,4,5,5 - hexafluoro - 1-piperideine (III) is very difficult to separate from phosphoryl chloride by fractional distillation. Therefore, purification of the reaction mixture was attempted by hydrolysis of the phosphoryl chloride. However, the reaction product (III) was also hydrolyzed to 2-chloro-6-oxo-3,3,4,4,5,5-hexafluoropiperideine (V) and the imide (I). Purification of III by repeated rectification can be avoided, however, if phenylphosphorus tetrachloride instead of phosphorus pentachloride is used as the chlorinating agent. In this case, phenylphosphonic dichloride instead of phosphoryl chloride is formed as a by-product which boils considerably higher than III, thus allowing isolation of III in high yield by one fractionation.



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(2) Preceding communication: H. Schroeder, E. Kober, H. Ulrich, R. Rätz, H. Agahigian, and C. Grundmann, *J. Org. Chem.*, **27**, 2580 (1962).

(3) R. N. Haszeldine, *J. Chem. Soc.*, 1966 (1950).

(4) J. H. Simons, U. S. Patent 2,490,098.

(5) R. N. Haszeldine and F. Smith, *J. Chem. Soc.*, 783 (1956).

(6) R. E. Banks, A. E. Ginsberg, and R. N. Haszeldine, *Proc. Chem. Soc.*, 211 (1960); R. E. Banks, A. E. Ginsberg, and R. N. Haszeldine, *J. Chem. Soc.*, 1740 (1961).

(7) E. Kober, H. Schroeder, R. Rätz, H. Ulrich, and C. Grundmann, *J. Org. Chem.*, **27**, 2577 (1962).

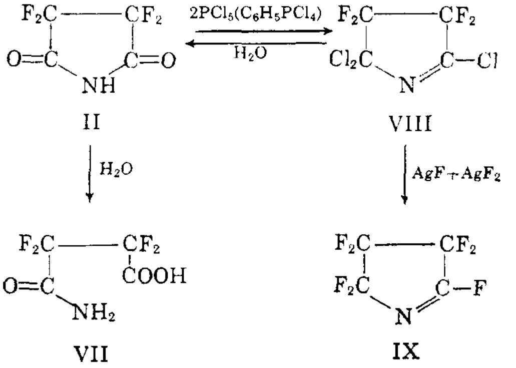
(8) H. Schroeder, R. Rätz, W. F. Schnabel, H. Ulrich, E. Kober, and C. Grundmann, *ibid.*, **27**, 2589 (1962).

(9) A. L. Henne and W. Zimmer, *J. Am. Chem. Soc.*, **73**, 1103 (1951).

Exchange of the chlorine atoms of compound III by fluorine was easily achieved by means of silver fluoride. The perfluoro-1-piperideine (VI) was thus obtained in good yield.

Tetrafluorosuccinimide (II) was similarily chlorinated with phosphorus pentachloride. In contrast to the isolation of compound III, separation of the chlorinated tetrafluorosuccinimide from phosphoryl chloride by repeated fractional distillation was not possible. When the reaction mixture was kept in an excess of water overnight in order to hydrolyze phosphoryl chloride, the sole product isolated was tetrafluorosuccinamic acid (VII). The treatment of the reaction mixture with water and immediate extraction with ether afforded II; with a small sample, however, the desired 2,5,5-trichloro-3,3,4,4-tetrafluoropyrroline (VIII) was obtained in low yield. Treatment with lead fluoride effected the desired conversion of the phosphoryl chloride into the gaseous phosphoryl fluoride, but it also resulted in the formation of by-products which affected adversely the yield of VIII. The best method to obtain pure VIII, was chlorination of II by means of phenylphosphorus tetrachloride. The separation of VIII from the high-boiling by-product, phenylphosphonic dichloride, was easily achieved by distillation.

Fluorination of VIII with silver fluoride resulted only in a low yield of the desired perfluoropyrroline (IX). Besides IX, partially fluorinated products were obtained which were converted into IX by means of silver difluoride.

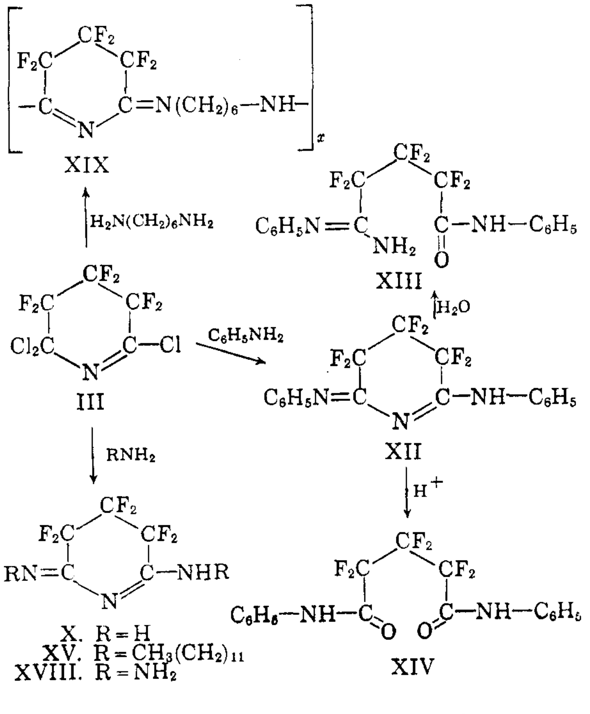


Although evidence for the formation of 1-piperideine and 1-pyrroline, the halogen-free parent compounds of III, VI and VIII, IX, respectively, has been reported,[10-12] they never have been isolated. Due to their structures as cyclic condensation products of aliphatic ω-aminoaldehydes, they are rather unstable and tend to trimerize to *sym*-hexahydrotriazine derivatives.[11,13] In the case of the perhalogenated 1-piperideines and 1-pyrrolines, the electron-withdrawing effect of the halogen groups lowers the basicity of the nitrogen atom to such an extent that the system no longer can undergo intermolecular condensation reactions.

To prove the assumed structures of the halogenated compounds III, VI, VIII, and IX, the trichloro derivatives were treated with ammonia and amines, respectively. Ammonolysis of III and VIII under various conditions, but preferably in excess liquid ammonia, gave 2-amino-6-imino-3,3,4,4,5,5-hexafluoro-1-piperideine (X) and its five-membered ring analog XI, respectively. Compound X was found to be identical in all respects with the cyclic imidine obtained from hexafluoroglutarodinitrile and liquid ammonia[14] according to:

$$NCCF_2CF_2CF_2CN + NH_3 \longrightarrow X$$

III and aniline gave 2-(*N*-phenylamino)-6-(*N*-phenylimino) - 3,3,4,4,5,5 - hexafluoro - 1 - piperideine (XII). XII, in methanolic solution, was hydrolyzed with water under ring cleavage to result in 2,2,3,3,4,4 - hexafluoro - 4 - *N'* - phenylamidinobutyranilide (XIII), while hydrolysis in boiling 2 *N* hydrochloric acid gave 2,2,3,3,4,4-hexafluoroglutaranilide (XIV). From dodecylamine and III, the 2-*N*-dodecylamino-6-*N*-dodecylimino - 3,3,4,4,5,5 - hexafluoro - 1 - piperideine (XV) was obtained. III and hydrazine gave the 2 - hydrazino - 6 - hydrazono - 3,3,4,4,5,5 - hexafluoro-1-piperideine (XVIII). III and hexanediamine-1,6 formed a polymeric material of low-molecular weight of the tentative structure XIX.



When VIII was treated with aniline, the reaction product consisted of 2-*N*-phenylamino-5-*N*-phenylimino-3,3,4,4-tetrafluoro-1-pyrroline (XVI) which,

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(10) P. J. G. Mann and W. R. Smithies, *J. Biochem.*, **61**, 89 (1955).

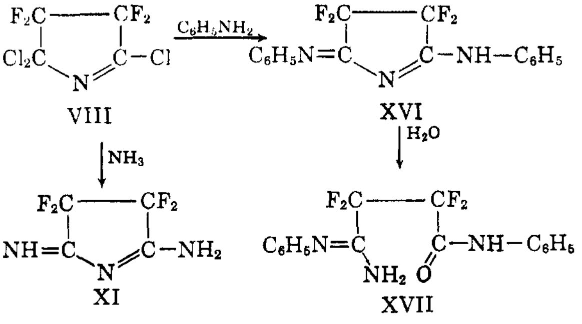
(11) D. W. Fuhlhage and C. A. Vander Werf, *J. Am. Chem. Soc.*, **80**, 6249 (1958).

(12) C. Schoepf and F. Oechler, *Ann.*, **523**, 1 (1936).

(13) C. Schoepf, A. Komzak, P. Braun, and E. Jakobi, *ibid.*, **559**, 1 (1948).

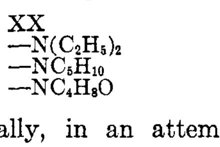
(14) H. C. Brown, *J. Polymer Sci.*, Vol. XLIV, **143**, 9 (1960).

however, underwent fast hydrolysis to give 2,2,3,3-tetrafluoro-3-*N′*-phenylamidinopropionanilide (XVII). Partial hydrolysis already occurred when the ether solution of XVI was washed with cold 2 *N* hydrochloric acid to remove excess aniline.



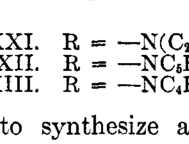
The reaction of the trichloro derivatives III and VIII with ammonia and primary amines constitutes a convenient method for the synthesis of cyclic perfluorinated imidines.

The reaction of III with 6 mole equivalents of secondary amines such as diethylamine, piperidine, and morpholine resulted in each case in the formation of the theoretical amount of the relevant amine hydrochlorides, thus indicating the complete replacement of the reactive chlorine atoms in 2- and 6- position by substituted amino groups. The primary reaction products, to which we assign the tentative structure XX, were not isolated; they are unstable, noncrystallizable oils which decomposed on attempted vacuum distillation. With traces of moisture the two amino groups in 6-position were hydrolytically cleaved to result in the formation of substituted 2-amino-6-oxo-1-piperideines (XXI–XXIII). The attempted reaction of III with ethyleneimine gave an oily product which decomposed vigorously upon heating.



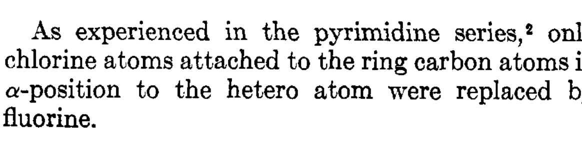
XX

R = $—N(C_2H_5)_2$
R = $—NC_5H_{10}$
R = $—NC_4H_8O$



XXI. R = $—N(C_2H_5)_2$
XXII. R = $—NC_5H_{10}$
XXIII. R = $—NC_4H_8O$

Finally, in an attempt to synthesize a fluorinated pyrrolenine by heating pentachloropyrrolenine (XXIV) with silver fluoride, 3,4-dichloro-2,2,5-trifluoropyrrolenine (XXV) was obtained.



As experienced in the pyrimidine series,[2] only chlorine atoms attached to the ring carbon atoms in α-position to the hetero atom were replaced by fluorine.

Experimental[15]

2,2,6-Trichloro-3,3,4,4,5,5-hexafluoro-1-piperideine (III).—(a). Perfluoroglutarimide (I, 76 g., 0.34 mole) was added with ice-cooling to phosphorus pentachloride (143 g., 0.68 mole). The mixture was heated in an oil bath at 150° for 15 hr. After approximately 1 hr., the reaction mixture became liquid upon vigorous evolution of hydrogen chloride. Repeated rectification of the reaction product through a Vigreux column yielded III, 70.6 g., (69%), b.p. 136–137°; n^{22}_{D} 1.4109. III has a characteristic acid chloride-like odor. (b). Hexafluoroglutarimide (I, 44.2 g., 0.20 mole) and phenylphosphorus tetrachloride (120 g., 0.48 mole) were refluxed until the evolution of hydrogen chloride ceased (*ca.* 15 hr.). Rectification of the reaction mixture yielded 55.9 g. (95%) of III, b.p. 135–136.5° (760 mm); n^{19}_{D} 1.4104.

Anal. Calcd. for $C_5Cl_3F_6N$: C, 20.39; Cl, 36.13; F, 38.70; N, 4.75. Found: C, 20.13, 19.93; Cl, 36.61, 36.38; F, 40.09, 39.83; N, 5.15, 4.98.

6-Oxo-3,3,4,4,5,5-hexafluoro-1-piperideinyl-(2)-tetrachlorophosphorane (IV).—Compound I (6.6 g., 0.03 mole) was added to phosphorus pentachloride (12.5 g., 0.06 mole). The reaction mixture was heated at 130° until the initial evolution of hydrogen chloride ceased (*ca.* 45 min.). Distillation yielded, in addition to 14 g. of a mixture of III and phosphoryl chloride, 2 g. (17%) of IV, b.p. 101° (4 mm.). The material reacted vigorously with water.

Anal. Calcd. for $C_5Cl_4F_6NO_2P$: C, 15.28; H-; Cl, 36.10; N, 3.56; P, 7.88. Found: C, 14.63, 14.42; H, 0.36, 0.10; Cl, 37.11; N, 4.12, 4.09; P, 6.96, 6.98.

2-Chloro-6-oxo-3,3,4,4,5,5-hexafluoro-1-piperideine (V).—The mixture of III and phosphoryl chloride was stirred with an excess of distilled water at 60° for 3 hr. Extraction with ether and distillation yielded, in addition to a minor amount of I (calcd. for C_5HF_6NO: N, 6.33; found: N, 6.05, 6.13), a main fraction, b.p. 111–112°, which analytical data indicated to be impure V.

Anal. Calcd. for C_5ClF_6NO: C, 25.06; Cl, 14.85; N, 5.87. Found: C, 24.7, 24.53; Cl, 17.77, 17.72; N, 4.72, 4.75.

Perfluoro-1-piperideine (VI).—Compound III (35 g.) was added in portions to finely powdered silver fluoride (100 g.). After each addition, an immediate vigorous reaction was observed. The crude VI, thus obtained, was rectified to yield 20.7 g. (71%) of pure VI, b.p. 43°; n^{22}_{D} 1.2800.

Anal. Calcd. for C_5F_9N: C, 24.50; F, 69.79; N, 5.71. Found: C, 24.35; F, 69.13; N, 5.72.

2,5,5-Trichloro-3,3,4,4-tetrafluoro-1-pyrroline (VIII).—(a). A mixture of perfluorosuccinimide[9] (II, 48.1 g., 0.28 mole) and phosphorus pentachloride (117 g., 0.56 mole) was refluxed until complete liquefaction had been achieved (*ca.* 20 hr.). Then, excess lead difluoride was added portionwise to the boiling reaction mixture. Distillation of the decanted liquid material yielded 59.2 g. of impure VIII, b.p. 103–114°. Attempts to obtain a pure product by fractional distillation failed, since all fractions still contained phosphoryl chloride. The addition of lead difluoride was repeated using small portions, since the lead difluoride evidently reacted only on the surface. Fractionation afforded pure VIII (16.8 g., 25%), b.p. 112–113°; n^{25}_{D} 1.4098, besides partially fluorinated materials. (b). Compound II (85.5 g., 0.50 mole) and phenylphosphorus tetrachloride (300 g., 1.2 moles) were refluxed until the evolution of hydrogen chloride ceased (*ca.* 5 hr.). Rectification of the reaction mixture yielded 110.3 g. (91%) of VIII; b.p. 112–114° (760 mm.); n^{25}_{D} 1.4092.

Anal. Calcd. for $C_4Cl_3F_4N$: C, 19.64; N, 5.72. Cl, 43.50; F, 31.00. Found: C, 19.82; N, 6.00, Cl, 43.09; F, 30.26.

Perfluorosuccinamic Acid.—A sample of the mixture of VIII and phosphoryl chloride was treated with water to give II, m.p. 63–64°. Upon standing overnight with an

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[15] Melting points were determined with the Fisher-Johns apparatus; analyses were by the Galbraith Microanalytical Laboratories, Knoxville, Tenn.

excess of water, II had been converted completely into *perfluorosuccinic monoamide*, m.p. 148–149° (from xylene).

Anal. Calcd. for $C_4H_3F_4NO_3$: N, 7.40. Found: N, 7.32, 7.48.

Perfluoropyrroline (IX).—Compound VIII (63 g., 0.258 mole) was added to excess silver fluoride (120 g.) to give 31 g. of crude reaction product. Fractional distillation yielded 3.2 g. of IX, b.p. 56–58°, and 21.1 g. of only partially fluorinated material, b.p. 58–114°. Since the fluorination with silver fluoride yielded the perfluoro compound only to a small extent, the partly fluorinated material (21.1 g.) was added to 35 g. of silver difluoride with ice-cooling. The exothermic reaction resulted in 13.1 g. of crude material which was rectified to yield another 3.1 g. of IX, b.p. 56–58°.

Anal. Calcd. for C_4F_7N: C, 24.03; N, 7.09; F, 68.28. Found: C, 24.17; N, 6.67; F, 67.31.

2-Amino-6-imino-3,3,4,4,5,5-hexafluoro-1-piperideine (X). (a). **From III and Liquid Ammonia.**—III (31.0 g., 0.105 mole) was added dropwise to an excess of liquid ammonia at −78°. After the addition was completed, the mixture was allowed to stand for 3 hr. Excess ammonia was evaporated at room temperature to leave a mixture consisting of X and ammonium chloride. Separation of these two components was achieved by extraction with three portions each of 100 ml. of diethyl ether. The combined extracts were evaporated to dryness to result in 23 g. (98%) of X, m.p. 162°.

Anal. Calcd. for $C_5H_3F_6N_3$: C, 27.41; H, 1.38; F, 52.03; N, 19.17. Found: C, 27.83, 28.01; H, 1.87, 1.97; F, 52.01, 52.34; N, 18.40, 18.38.

(b). **From Hexafluoroglutarodinitrile and Ammonia.**[14]—Hexafluoroglutarodinitrile (3.2 g.) was added dropwise to an excess of condensed ammonia at −78°. After stirring for 15 min., the excess ammonia was removed by slow evaporation. The solid residue, consisting of X (3.3 g. = 95%), m.p. 161–163°, was washed with dry petroleum ether and analyzed without further recrystallization.

Anal. Calcd. for $C_5H_3F_6N_3$: C, 27.41; H, 1.38; F, 52.03; N, 19.18. Found: C, 27.23, 27.02; H, 1.66, 1.68; F, 51.98, 51.57; N, 18.90, 18.90.

(c). **From III and Ammonia in Benzene.**—Compound III (10 g., 0.034 mole) was added dropwise at 0° to 150 ml. of dry benzene saturated with gaseous ammonia. The precipitated ammonium chloride was removed by filtration. Evaporation of the solvent gave 4.1 g. of X; white crystals, m.p. 170–173°.

Anal. Calcd. for $C_5H_3F_6N_3$: C, 27.41; H, 1.38. Found: C, 27.53, 27.31; H, 1.38, 1.53.

(d). **From III and Aqueous Ammonia.**—Compound III (11.0 g., 0.038 mole) was added dropwise, with stirring, to 60 ml. of 25% aqueous ammonia (~0.83 mole of NH_3) at −10° over a period of 30 min. The product was collected and extracted with 25 ml. of cold water to give a residue consisting of 1.003 g. (12.6%) of III, m.p. 164°.

2-*N*-Phenylamino-6-*N*-phenylimino-3,3,4,4,5,5-hexafluoro-1-piperideine (XII), 2,2,3,3,4,4-Hexafluoro-4-*N*′-phenylamidinobutyranilide (XIII), and 2,2,3,3,4,4-Hexafluoroglutaranilide (XIV).—To the ice-cooled stirred solution of 18 g. (0.196 mole) of aniline in 150 ml. of dry ether, 10 g. (0.034 mole) of 2,2,6-trichloro-3,3,4,4,5,5-hexafluoro-1-piperideine (III) was added dropwise. An immediate precipitation of aniline hydrochloride was observed. After stirring at room temperature for 2 hr., the precipitate was removed and, upon evaporation of the filtrate *in vacuo*, 12.2 g. of a solid reaction product, m.p. 143–145°, was obtained. Recrystallization from ligroin yielded 7.7 g. (62%) of XII, m.p. 144–146°.

Anal. Calcd. for $C_{17}H_{11}F_6N_3$: C, 54.99; H, 2.98; N, 11.31. Found: C, 55.21, 55.27; H, 3.03, 3.21; N, 10.94, 10.89.

When compound XII was treated with aqueous methanol, in addition to XII which settled on the bottom of the flask as an oil, colorless leaflets consisting of XIII, m.p. 176–177°, crystallized from the solvent.

Anal. Calcd. for $C_{17}H_{13}F_6N_3O$: C, 52.41; H, 3.35; N, 10.81. Found: C, 51.88, 51.86; H, 3.62, 3.74; N, 10.03, 10.08.

For complete hydrolysis, XII was dissolved in methanol and, after addition of 2 *N* hydrochloric acid refluxed for 5 hr. After 15 min., the precipitation of colorless leaflets started. After cooling, the precipitate was removed. Recrystallization from ethanol gave XIV, m.p. 202–203°.

Anal. Calcd. for $C_{17}H_{12}F_6N_2O_2$: C, 52.31; H, 3.09; N, 7.17. Found: C, 52.17, 52.28; H, 2.52, 2.40; N, 7.31, 7.44.

2-*N*-Dodecylamino-6-*N*-dodecylimino-3,3,4,4,5,5-hexafluoro-1-piperideine (XV).—Analogous to the reaction with aniline, XV was obtained from III and dodecylamine in a 83% yield. Recrystallization from acetic anhydride gave white crystals which melted at 57–58°.

Anal. Calcd. for $C_{29}H_{51}F_6N_3$: N, 7.58. Found: N, 7.85, 7.68.

2-Hydrazino-6-hydrazono-3,3,4,4,5,5-hexafluoro-1-piperideine (XVIII).—To 5.5 g. (0.17 mole) of 94% hydrazine in 100 ml. of absolute ethanol, 10 g. (0.034 mole) of III were added with stirring and ice-cooling. An immediate orange coloration and precipitation of hydrazine hydrochloride was observed. After standing for 1 hr., the precipitate was removed and, upon evaporation of the filtrate *in vacuo*, a semisolid, reddish brown product was obtained which partially solidified after addition of ethanol. Thus, 5.8 g. (70%) of a yellowish brown reaction product, m.p. 130–170° dec., was obtained. Purification was achieved by treating with methanol–ether. The still amorphous XVIII melted at 161–172° dec.

Anal. Calcd. for $C_5H_5F_6N_5$: C, 24.10; H, 2.05. Found: C, 24.01, 23.99; H, 2.17, 2.38.

Product from Hexanediamine-1,6 and 2,2,6-Trichloro-3,3,4,4,5,5-hexafluoro-1-piperideine (III).—To the solution of 20 g. (0.17 mole) of hexanediamine-1,6 in 100 ml. of ether, 10 g. (0.034 mole) of III were added with stirring and ice-cooling. After the calculated amount of hexanediamine hydrochloride had been removed, evaporation of the filtrate yielded 4.5 g. (45%) of a white solid, m.p. 255–257° dec. After recrystallization from acetic anhydride, the product melted at 259° dec. Analytical data indicated that this material had a composition corresponding to structure XIX.

Anal. Calcd. for $(C_{11}H_{13}F_6N_3)_x$: C, 43.86; H, 4.34; N, 13.95. Found: C, 42.85, 43.08; H, 4.28, 4.18; N, 13.27, 13.24.

2-Piperidino-6-oxo-3,3,4,4,5,5-hexafluoro-1-piperideine (XXII).—To piperidine (17.5 g.) in 150 ml. of dry ether, III (10 g.) was added dropwise with stirring and ice-cooling. After stirring at room temperature for 2 hr., the calculated amount of piperidine hydrochloride (12.5 g.) was removed. Evaporation of the ether yielded the tripiperidino compound (14.9 g., 99.3%) as a viscous oil which crystallized on standing at −15°. Attempts to recrystallize this material failed. During the attempted distillation *in vacuo*, decomposition at 120° (3 mm.) was observed. On further heating, a yellow oil distilled at 120–140° (3 mm.) which crystallized on standing. Recrystallization from ligroin yielded XXII in the form of colorless needles; m.p. 68–69°.

Anal. Calcd. for $C_{10}H_{10}F_6N_2O$: C, 41.66; H, 3.50; N, 9.72. Found: C, 41.64, 41.75; H, 3.78, 3.56; N, 9.91, 10.14.

2-Morpholino-6-oxo-3,3,4,4,5,5-hexafluoro-1-piperideine (XXIII).—Analogous to the reaction with piperidine a small amount of XXIII was obtained by treating III with morpholine; white needles, m.p. 127–129° (from ligroin).

Anal. Calcd. for $C_9H_8F_6N_2O_2$: C, 37.25; H, 2.77; N, 9.64. Found: C, 37.18, 37.20; H, 3.13, 3.25; N, 9.87, 9.96.

2-Diethylamino-6-oxo-3,3,4,4,5,5-hexafluoro-1-piperideine (XXI).—Analogous to the reaction with piperidine, XXI was obtained by treating III with diethylamine; light yellow oil, b.p. 135–136° (11 mm.); yield 29%.

Anal. Calcd. for $C_9H_{10}F_6N_2O$: C, 39.10; H, 3.62. Found: C, 39.95, 40.04; H, 4.38, 4.28.

2-Amino-5-imino-3,3,4,4-tetrafluoropyrroline (XI).—Compound VIII (89 g.) was added, with stirring, to an excess of ammonia maintained at −80°. After 1 hour, the excess of ammonia was evaporated and the remainder extracted with ether and subsequently with absolute ethanol. Evaporation of the solvents yielded 12.2 g. of XI; white needles from acetone. No melting was observed when a sample was heated under the usual conditions at the Fisher-Johns plate, since the product was converted by heat with loss of ammonia into a higher molecular weight condensation product.

Anal. Calcd. for $C_4H_3F_4N_3$: C, 28.35; H, 1.78; F, 44.94; N, 24.84. Found: C, 29.28; H, 2.50; F, 43.63; N, 24.22.

2,2,3,3-Tetrafluoro-3-*N*′-phenylamidinopropionanilide (XVII).—To a solution of 5.9 g. (0.064 mole) of aniline in 80 ml. of dry ether, 3 g. (0.012 mole) of VIII was added dropwise, with stirring, at 0°. After stirring for several hours, the aniline hydrochloride was removed. Evaporation of the ether yielded a solid reaction product contaminated with aniline. This material was dissolved in ether and washed with 2 *N* hydrochloric acid. Upon evaporation of the ether, 1.5 g. of solid material was obtained which, after extraction with boiling ligroin, melted at 166–168°. Recrystallization from ethanol–water (1:1) yielded XVII, white needles, m.p. 168°.

Anal. Calcd. for $C_{16}H_{13}F_4N_3O$: N, 12.38. Found: N, 12.07, 11.94.

Cooling of the ligroin extract resulted in the precipitation of white crystals, m.p. 130–132°, presumably 2-*N*-phenylamino-5-*N*-phenylimino-3,3,4,4-tetrafluoro-1-pyrroline (XVI).

3,4-Dichloro-2,2,5-trifluoropyrrolenine (XXV).—Pentachloropyrrolenine[16] (112 g.) was allowed to react with excess silver fluoride (300 g.) at 135° for 2 hr. The reaction product was distilled in a moderate vacuum to yield, in addition to 16.5 g. of a liquid fraction, 39.6 g. (44%) of XXV. Recrystallization of the latter from petroleum ether (b.p. 90–97°) gave white needles, m.p. 107.5–108.5°.

Anal. Calcd. for $C_4Cl_2F_3N$: C, 25.32; Cl, 37.27; F, 29.98; N, 7.43. Found: C, 25.38; Cl, 37.19; F, 28.57; N, 8.39.

The liquid material boiled under atmospheric pressure at 123–125°. Analytical values indicate that this material is *dichloromaleoyl fluoride.*

Anal. Calcd. for $C_4Cl_2F_2O_2$: C, 25.37; F, 20.16. Found: C, 24.96; F, 21.92; N, none.

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[16] R. Anschütz and G. Schroeter, *Ann.*, **295**, 82 (1896). The literature prescription had to be modified using 5.5 instead of 4 moles of phosphorus pentachloride. Otherwise little or no pentachloropyrrolenine was obtained.

Synthesis of Polyfluorinated Heterocycles by Indirect Fluorination with Silver Fluorides. IV. Fluorothiadiazoles[1,2]

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The reaction of 2,5-dibromo-1,3,4-thiadiazole with silver fluoride gave 2-bromo-5-fluoro-1,3,4-thiadiazole and isocyanogen tetrafluoride which was also prepared from the respective tetrabromide. 3-Perfluoroalkyl-5-fluoro-1,2,4-thiadiazoles were obtained in a two-step synthesis by reaction of perhalogenated alkylamidines with trichloromethanesulfonyl chloride, and fluorination of the reaction products with silver fluoride, in one case with SbF_3Cl_2 (Swarts mixture).

In the previous publications of this series[2–4] the advantage of using silver fluorides as inorganic fluorinating agents for the preparation of perfluorinated aza-aromatic heterocycles from the appropriate chloro compounds has been demonstrated. It seemed desirable to extend these studies to the synthesis of perfluoro heterocycles containing sulfur in addition to nitrogen. This work concerns the fluorination of certain chlorinated and brominated thiadiazoles.

The reaction of 2,5-dibromo-1,3,4-thiadiazole[5] (I) with silver fluoride did not give the desired difluorinated compound but 2-bromo-5-fluoro-1,3,4-thiadiazole (II). The yield was only 16%, since compound I decomposed to a considerable extent upon treatment with silver fluoride. From the same reaction, besides II a low-boiling by-product was obtained, the analysis of which agreed with the formula of isocyanogen tetrafluoride (III), $F_2C{=}N{-}N{=}CF_2$. For proof of structure, III was prepared by an independent synthesis from isocyanogentetrabromide[6] (IV). Fluorination with SbF_3Cl_2 (Swarts mixture) failed but the conversion was achieved by means of silver fluoride in 23% yield. The samples, the degradation product from the reaction of I with silver fluoride and the product of the reaction of IV with silver fluoride, were identical.

Other attempts to prepare 2,5-difluoro-1,3,4-thiadiazole (V) were also unsuccessful. Compound II could not be converted to V by means of AgF or AgF_2. The reaction of I with SbF_3Cl_2 (Swarts

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[2] Preceding communication: H. Ulrich, E. Kober, H. Schroeder, R. Rätz, and C. Grundmann, *J. Org. Chem.*, **27**, 2585 (1962).

[3] H. Schroeder, E. Kober, H. Ulrich, R. Rätz, H. Agahigian, and C. Grundmann, *J. Org. Chem.*, **27**, 2580 (1962).

[4] E. Kober, H. Schroeder, R. Rätz, H. Ulrich, and C. Grundmann, *J. Org. Chem.*, **27**, 2577 (1962).

[5] R. Stollé and K. Fehrenbach, *J. prakt. Chem.*, [2] **122**, 306 (1929).

[6] J. Thiele, *Ann.*, **303**, 57, 70 (1898).