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FLUOROCARBON DERIVATIVES OF NITROGEN. PART I. SOME REACTIONS OF PERFLUORO-1-AZACYCLOHEXENE

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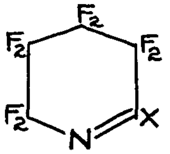
SUMMARY



(I) X = F ; (II) X = NMe_2 ; (III) X = NEt_2

(IV) X = $\overline{N(CH_2)_2OCH_2CH_2}$; (V) X = OC_6Cl_5 ;

(VI) X = $ON(CF_3)_2$

Controlled displacement of fluorine from perfluoro-1-azacyclohexene (I) by the nucleophilic reagents Me_2NH, Et_2NH, $\overline{CH_2CH_2O(CH_2)_2N}H$, C_6Cl_5ONa, and $(CF_3)_2NONa$ provides the derivatives (II) - (VI), respectively. The last of these can also be obtained by treatment of the parent compound (I) with mercury^{II} bistrifluoromethylnitroxide.

INTRODUCTION

Like its trichloro-analogue (VII) [1], perfluoro-1-azacyclohexene (I) readily suffers loss of halogen from both the C2 and C6 sites when treated with an excess of a suitable nucleophile, e.g., ammonia $\{\longrightarrow$ (VIII) [2]$\}$, sodium methoxide $\{\longrightarrow$(IX) [3]$\}$, and sodium phenoxide $\{\longrightarrow$(X) [2,4]$\}$. Products arising from replacement of only the fluorine of the imidoyl group in the azacyclohexene (I) have been isolated from reactions involving perfluoroisopropylcaesium $\{\longrightarrow$(XI) [5]$\}$, piperidine $\{\longrightarrow$ (XII) [6]$\}$, and *N*-alkylanilines $\{\longrightarrow$(XIII) [7]$\}$, but only in the case of the first of these was

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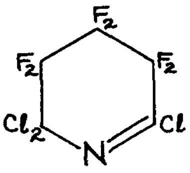
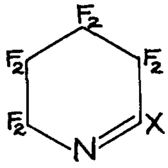
such an outcome the primary objective of the work. This report concerns further experiments designed to provide 2-substituted octafluoro-1-azacyclohexenes.



(VII)

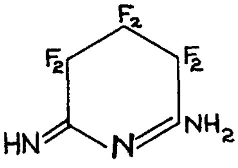


(I) X = F

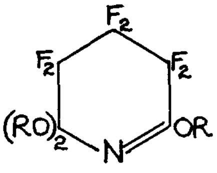
(XI) X = $CF(CF_3)_2$

(XII) X = $\overline{N(CH_2)_4CH_2}$

(XIII) X = NRPh (R = Me or Et)



(VIII)

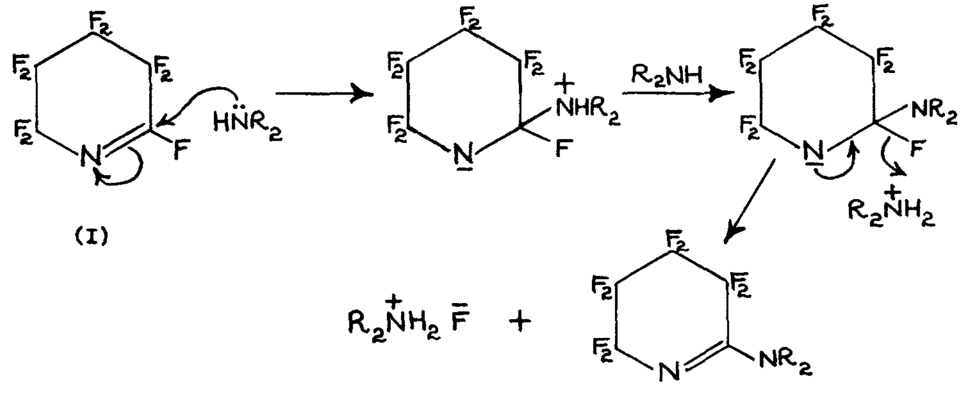


(IX) R = Me

(X) R = Ph

RESULTS AND DISCUSSION

Treatment of perfluoro-1-azacyclohexene with a two-molar proportion of dimethylamine, diethylamine, or morpholine under mild conditions (20 °C or below) leads to smooth replacement of the fluorine of the N=CF group, presumably via a nucleophilic addition-elimination mechanism (Ad_N-E), with the formation of the new derivatives (II)-(IV). Similarly,



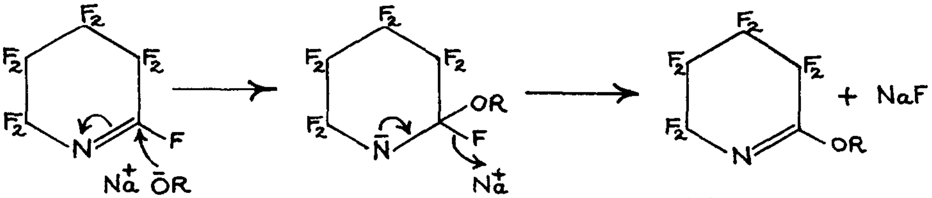
(II) R_2 = Me_2

(III) R_2 = Et_2

(IV) R_2 = $(CH_2)_2O(CH_2)_2$

SCHEME 1

interaction of the azacyclohexene with one molar proportion of sodium pentachlorophenoxide or sodium bistrifluoromethylnitroxide yields imidic esters (V) and (VI), respectively. The elimination leg of an Ad_N-E mechanism for an imidoyl halide—amine system can be written in several ways which differ according to the timing and mode of deprotonation of the zwitterion formed in the addition step [8]; at present, the perfluoro-1-azacyclohexene—R_2NH reaction seems best depicted as in Scheme 1. Obviously, a reaction involving a sodium salt presents a simpler problem (see Scheme 2).

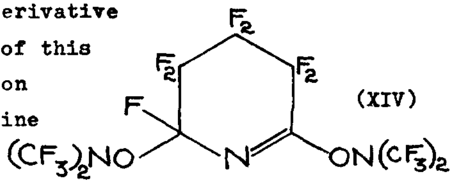


SCHEME 2

(V) OR = OC_6Cl_5

(VI) OR = $ON(CF_3)_2$

Treatment of perfluoro-1-azacyclohexene with the mercurial $[(CF_3)_2NO]_2Hg$ also provides compound (VI), together with material believed to be the di-substituted derivative (XIV). Discussion of the mechanism of this reaction is deferred until studies on electrophilic substitution of fluorine in the azacyclohexene and related compounds are complete.



(XIV)

Structures (II)-(VI) and (XIV) were established by elemental analysis and spectroscopic methods. If loss of fluoride had occurred from position 6, rather than 2, of the presumptive nitranion intermediates shown in Schemes 1 and 2, the ^{19}F n.m.r. spectrum of each final product would have contained an imidoyl fluorine absorption well to low field of external trifluoroacetic acid [δ_F(C$\underline{F}$=N) for (I) = +24.2 p.p.m.]; in fact, all ring fluorine absorptions appeared in the region -2.2 to -59.3 p.p.m. Not surprisingly, the maximum shift to longer wavelength of the i.r. C=N str. absorption for perfluoro-1-azacyclohexene [$\lambda_{max.}$ 5.70 μm] occurred when the imidoyl fluorine was replaced by a dialkylamino function [$\lambda_{max.}$(III) = 6.17 μm].

EXPERIMENTAL

Spectroscopy

I.r., n.m.r. [shifts to high field of references designated negative], and mass spectroscopic analyses, respectively, were carried out with a Perkin-Elmer spectrophotometer model 257, a Perkin-Elmer R10 instrument (^{19}F at 56.46 and ^{1}H at 60 MHz), and a G.E.C.-A.E.I. MS902 spectrometer (electron beam energy 70 eV). The ^{19}F n.m.r. reference was ext. CF_3CO_2H.

Starting Materials

(a) Perfluoro-1-azacyclohexene

This was obtained by defluorination (with triphenylphosphine [5]) of perfluoro-N-fluoropiperidine procured by Simons' electrochemical fluorination of pyridine [10].

(b) NN-Bistrifluoromethylhydroxyxlamine

Trifluoronitrosomethane, prepared by pyrolysis of trifluoroacetyl nitrite [11], was converted into NN-bistrifluoromethylhydroxylamine by treating it with ammonia [12] according to a method devised by Connell [13] and improved by P. B. S. Luckman of this Department. The reaction vessel comprised a round-bottomed Quickfit flask (100 cm^3) connected to, and surmounted by, a Pyrex storage bulb (ca. 23 l) which was attached to a standard vacuum line *via* a Rotaflo Fluon-glass stopcock (TF 6/13). Trifluoronitrosomethane (78.75 g, 0.795 mole) was divided equally between two such reaction vessels (both attached to the same vacuum line; pressure in each, 295 mmHg) then gaseous ammonia (total 13.60 g, 0.80 mole) was introduced quickly; immediately, a fine mist formed in each bulb, and droplets of a colourless liquid began to appear on the walls and run down into the collection flasks. After 24 h, the residual gases in the apparatus were removed using a water pump (note that trifluoronitrosomethane reacts vigorously with ammonia in the liquid phase, so co-condensation of these in a cold 'muck trap' protecting a vacuum pump should be avoided); the liquid product was then transferred, *in vacuo* (continuous pumping), from the collection flasks to two traps (in series) cooled to -78 °C, leaving behind an unidentified white solid. When the material (73.0 g) condensed at -78 °C was warmed to room temperature, it separated into two liquid phases, the upper being mainly water. The pale-yellow lower layer (>90% of the total volume) was divided into two approximately equal portions, and each was added dropwise in separate experiments to stirred, finely-powdered phosphorus pentoxide (100 g) contained in a flask (250 cm^3) equipped with a water-cooled reflux condenser leading to a cold (-78 °C) trap and swept with a slow stream of nitrogen. In each experiment, dehydration was allowed to proceed for 6 h. The combined yield of *NN*-bistrifluoromethylhydroxylamine (collected at -78 °C) was 55.8 g (0.33 mole, 83%).

(c) Mercury^{II} Bistrifluoromethylnitroxide

NN-Bistrifluoromethylhydroxylamine (14.3 g, 0.085 mole) was condensed, *in vacuo*, on to dry silver^{II} oxide (19.6 g, 0.158 mole) [14] contained in a cold (-196 °C) Pyrex ampoule (250 cm^3). The ampoule was sealed, allowed to warm to room temperature, and then stored in the dark for 16 h. The volatile product was passed over phosphorus pentoxide then distilled, to give bistrifluoromethyl nitroxide (13.8 g, 0.083 mole, 98%). This was converted into mercury^{II} bistrifluoromethylnitroxide by shaking it with an excess of mercury as described in the literature [15].

Reactions of perfluoro-1-azacyclohexene

(a) With dimethylamine

Perfluoro-1-azacyclohexene (2.35 g, 9.59 mmole) and dimethylamine (0.908 g, 20.2 mmole) were condensed separately into a cold (-196 °C) evacuated Pyrex ampoule (60 cm^3). The ampoule was sealed and allowed to warm to room temperature; after 1 h, the liquid product was distilled to provide 2-dimethylamino-3,3,4,4,5,5,6,6-octafluoro-1-azacyclohexene (nc)(2.10 g, 7.78 mmole, 81%)[Found: C, 31.2; H, 2.2; N, 10.3%; *M* (mass spec.), 270. $C_7H_6F_8N_2$ requires C, 31.1; H, 2.2; N, 10.4%; *M*, 270], b.p. 83 °C, δ_F -3.0 ($C\underline{F}_2N$), -34.0 ($C\underline{F}_2CNMe_2$), and -55.0 p.p.m. ($C\underline{F}_2C\underline{F}_2CF_2N$), δ_H τ6.75, $\lambda_{max.}$ (film) 6.15 μm (C=N str.).

(b) With diethylamine

Perfluoro-1-azacyclohexene (1.62 g, 6.61 mmole) was added slowly to a stirred solution of diethylamine (1.21 g, 16.6 mmol) in light petroleum (25 cm^3; b.p. 40-60 °C) cooled to 0 °C. The mixture was allowed to warm to room temperature, stirred for 2 h, and then filtered to remove diethylamine hydrofluoride; distillation of the filtrate provided 2-diethylamino-3,3,4,4,5,5,6,6-octafluoro-1-azacyclohexene (nc)(1.20 g, 4.03 mmole, 61%)[Found: C, 36.2; H, 3.5; F, 50.8; N, 9.5%; $\underline{M}$ (mass spec.), 298. $C_9H_{10}F_8N_2$ requires C, 36.2; H, 3.4; F, 51.0; N, 9.4%; $\underline{M}$, 298), b.p. 55 °C at ca. 1 mmHg, δ_F (soln. in CCl_4) -2.2 ($C\underline{F}_2N$), -35.0 ($C\underline{F}_2CNEt_2$), and -56.5 ($C\underline{F}_2C\underline{F}_2CF_2N$) p.p.m., δ_H (ext. C_6H_6) -3.0 (CH_2, q, $\underline{J}$ 7.0 Hz) and -5.3 (CH_3, t) p.p.m., $\lambda_{max.}$ (film) 6.17 µm (C=N str.).

(c) With morpholine

Perfluoro-1-azacyclohexene (2.87 g, 11.7 mmole) was added slowly to a stirred solution of morpholine (1.98 g, 22.75 mmole) in light petroleum (15 cm^3; b.p. 60-80 °C) at room temperature. Removal of solid morpholine hydrofluoride from the product followed by distillation provided 3,3,4,4,5,5,6,6-octafluoro-2-morpholino-1-azacyclohexene (nc) (2.41 g, 7.72 mmole, 66%)[Found: C, 34.5; H, 2.5; N, 9.2%; M (mass spec.), 312. $C_9H_8F_8N_2O$ requires C, 34.6; H, 2.6; N, 9.0%; M, 312], m.p. 43 °C, b.p. 134 °C at ca. 1 mmHg, δ_F (soln. in CCl_4) -4.0 ($C\underline{F}_2N$), -34.0 ($C\underline{F}_2C\overline{NCH_2CH_2OCH_2C}H_2$), and -56.0 ($C\underline{F}_2C\underline{F}_2CF_2N$) p.p.m., $\lambda_{max.}$ (melt) 6.17 µm (C=N str.).

(d) With sodium pentachlorophenoxide

Perfluoro-1-azacyclohexene (4.68 g, 19.1 mmole) was added during 40 min. to a stirred suspension of sodium pentachlorophenoxide (5.54 g, 19.2 mmol) in diethyl ether (60 cm^3) at room temperature. The product was filtered and the filtrate was evaporated; the residue was recrystallised from diethyl ether to give 3,3,4,4,5,5,6,6-octafluoro-2-pentachlorophenoxy-1-azacyclohexene (nc)(7.42 g, 15.1 mmole, 79%) (Found: C, 27.1; N, 2.8. $C_{11}Cl_5F_8NO$ requires C, 26.85; N, 2.8%), m.p. 117 °C, δ_F (soln. in CCl_4) -11.0 ($C\underline{F}_2N$), -41.3 ($C\underline{F}_2COC_6Cl_5$), -55.0 ($C\underline{F}_2CF_2N$), -56.4 ($C\underline{F}_2CF_2CF_2N$) p.p.m., $\lambda_{max.}$ (mull) 5·86 µm (C=N str.).

(e) With sodium bistrifluoromethylnitroxide

Perfluoro-1-azacyclohexene (7.13 g, 29.1 mmole) was added slowly to a stirred solution of sodium bistrifluoromethylnitroxide (5.75 g, 30.1 mmole) in diethyl ether (15 cm^3) in an atmosphere of dry nitrogen (the reagent was prepared by adding $\underline{NN}$-bistrifluoromethylhydroxylamine to a suspension of sodium in ether). The reaction mixture was stirred at room temperature for 3 days then filtered; the filtrate was distilled to give perfluoro-1-azacyclohexene (4.98 g, 70% recovery) and perfluoro-(2-dimethylamino-oxy-1-azacyclohexene)(2.40 g, 6.09 mmole, 70% based on C_5F_9N consumed), identified by comparison of its i.r. spectrum with that of the material obtained from the azacyclohexene and mercury(II) bistrifluoromethylnitroxide (see below).

(f) With mercury^{II} bistrifluoromethylnitroxide

Perfluoro-1-azacyclohexene (3.70 g, 15.1 mmole) contaminated with perfluoro-n-pentane [a byproduct of the electrochemical fluorination of pyridine, the method used to obtain the precursor of the azacyclohexene (see above)] was condensed, *in vacuo*, into a cold (-196 °C) Pyrex tube (30 cm^3) equipped with a PTFE needle valve and containing mercury^{II} bistrifluoromethylnitroxide (7.70 g, 11.4 mmole) and mercury. The valve was closed and the tube was allowed to warm to room temperature during 1 h; after the tube had been shaken mechanically for 10 days, the volatile product was distilled to yield perfluoro-n-pentane (0.30 g), identified by i.r. spectroscopy and g.l.c. analysis, and perfluoro-(2-dimethylamino-oxy-1-azacyclohexene)(nc)(3.50 g, 8.89 mmol, 59%) [Found: C, 21.3; N, 7.1%; M (mass spec.), 394. $C_7F_{14}N_2O$ requires C, 21.3; N, 7.1%; M, 394], b.p. 101 °C (Siwoloboff), δ_F (neat liq.) +8.2 [$(C\underline{F}_3)_2NO$], -15.4 ($C\underline{F}_2N$), -44.2 ($CF_2C{=}N$), -58.4 ($C\underline{F}_2CF_2N$ or $CF_2CF_2CF_2N$), and -59.3 ($C\underline{F}_2CF_2N$ or $C\underline{F}_2CF_2CF_2N$) p.p.m. (rel. int. 3:1:1:1:1), $\lambda_{max.}$ (film) 5.78 μm (C=N str.). The colourless, liquid, distillation residue gave only one g.l.c. peak (2 m SE30) and possessed properties consistent with perfluoro-[2,6-bis(dimethylamino-oxy)-1-azacyclohexene](nc)(0.50 g, 0.73 mmole, 6%)[Found: C, 20.3; N, 7.8%; M (mass spec.), 543. $C_9F_{19}N_3O_2$ requires C, 19.9; N, 7.7%; M, 543], δ_F (neat liq.) +9.4 [$(C\underline{F}_3)_2NOCF$], +8.4 [$(C\underline{F}_3)_2NOC{=}N$], -19.0 [$(CF_3)_2NOC\underline{F}$], -43.7 ($C\underline{F}_2C{=}N$), and 56.0—59.2 ($C\underline{F}_2C\underline{F}_2CF_2C{=}N$) p.p.m. (rel. int. 6:6:1:2:4), $\lambda_{max.}$ 5.76 μm (C=N str.).

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REFERENCES

1 H. Ulrich, E. Kober, H. Schroeder, R. Rätz, and C. Grundmann, J. Org. Chem., 27 (1962), 2585.

2 C. Oppenheim, Ph.D. Thesis, University of Manchester, 1970.

3 R. Hatton, Ph.D. Thesis, University of Manchester, 1967. The trimethoxy-compound (IX) is also formed when perfluoro-N-fluoropiperidine is treated with sodium methoxide in methanol, presumably via defluorination of the N-fluoro-compound to give perfluoro-1-azacyclohexene (cf. ref. 4). J. F. Liebman and B. B. Jarvis will find that result interesting [see J. Fluorine Chem., 5 (1975), 46].

4 V. R. Polishchuk and L. S. German, Tetrahedron Letters, (1972) 5169. The perfluoro-1-azacyclohexene was formed in situ through attack by sodium phenoxide on perfluoro-N-fluoropiperidine, a process which also leads to the production of o- and p-fluorophenol.

5 R. E. Banks, K. Mullen, W. J. Nicholson, C. Oppenheim, and A. Prakash, J. Chem. Soc. Perkin Trans. I, (1972) 1098.

6 R. E. Banks, R. N. Haszeldine, and R. Hatton, Tetrahedron Letters, (1967) 3993. Initially, perfluoro-1-azacyclohexene was generated in situ by attack on perfluoro-N-fluoropiperidine by piperidine, which leads to the formation of N-fluoropiperidine.

7 V. R. Polishchuk, B. Ya. Medvedev, N. N. Bubnov, L. S. German, and I. L. Knunyants, Bull. Acad. Sci. U.S.S.R., Ser. Chem., (1972) 2736. Compounds (XIII) plus perfluoro-1-azacyclohexene and NN-dialkyl-o-fluoroanilines were formed during reactions between perfluoro-N-fluoropiperidine and the NN-dialkylanilines $PhNR_2$ (R = Me or Et); dealkylation of the dialkylanilines followed by attack of the resulting monoalkylanilines on the 1-azacyclohexene was postulated.

8 Z. Rappoport and R. Ta-Shma, Tetrahedron Letters, (1971) 3813; J. Amer. Chem Soc., 99 (1977), 1845.

9 R. E. Banks, J. V. Latham, and C. Oppenheim, work in progress.

10 R. E. Banks, A. E. Ginsberg, and R. N. Haszeldine, J. Chem. Soc., (1961) 1740.

11 R. E. Banks, K. C. Eapen, R. N. Haszeldine, A. V. Holt, T. Myerscough, and S. Smith, J. Chem. Soc. Perkin Trans. I, (1974) 2532.

12 S. P. Makarov, A. Ya. Yakubovich, S. S. Dubov, and A. N. Medvedev, Dokl. Akad. Nauk S.S.S.R., 160 (1965), 1319.

13 D. L. Connell, Ph.D. Thesis, University of Manchester, 1970.

14 H. G. Ang, Chem. Comm., (1968) 1320.

15 H. J. Emeléus, J. M. Shreeve, and P. M. Spaziante, J. Chem. Soc. (A), (1969) 431; R. E. Banks, D. R. Choudhury, and R. N. Haszeldine, J. Chem. Soc. Perkin Trans. I, (1973) 1092.