Journal of Fluorine Chemistry, 14 (1979) 383–401

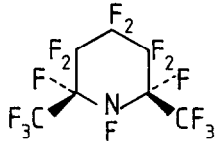
Received: April 19, 1979

FLUOROCARBON DERIVATIVES OF NITROGEN. PART III [1]. OBSERVATIONS ON THE SYNTHESIS OF PERFLUORO-(2,6-DIMETHYL-1-AZACYCLOHEXENE) VIA ELECTROCHEMICAL FLUORINATION OF 2,6-DIMETHYLPYRIDINE, AND ITS CONVERSION INTO 6-SUBSTITUTED 3,3,4,4,5,5-HEXAFLUORO-2,6-BIS(TRIFLUOROMETHYL)-1-AZA-CYCLOHEXENES

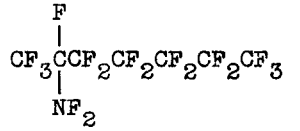
R.E. BANKS*, M.G. BARLOW, and M. NICKKHO-AMIRY

Chemistry Department, The University of Manchester Institute of Science and Technology, Manchester M60 1QD (Great Britain)

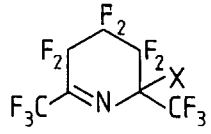
SUMMARY



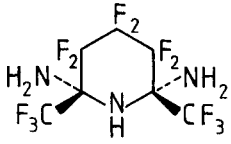
(I)



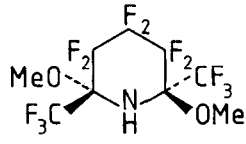
(II)



(III) X = F; (IV) X = OMe;
(V) X = $ON(CF_3)_2$; (VI) X = $CF(CF_3)_2$;
(VII) X = NEt_2; (VIII) X = NHPh



(IX)



(X)

* To whom enquiries should be addressed.

Large-scale Simons' electrochemical fluorination of 2,6-dimethylpyridine yielded a complex mixture containing perfluoro-[N-fluoro-2(e),6(e)-dimethylpiperidine] (I) and its ring-opened analogue perfluoro-(NN-difluoro-2-aminoheptane) (II). Defluorination of the N-fluoropiperidine with triphenylphosphine gave perfluoro-(2,6-dimethyl-1-azacyclohexene) (III), which was converted into derivatives (IV) - (VIII) through treatment with nucleophilic reagents [MeONa, $(CF_3)_2NOH.CsF$, $(CF_3)_2CFCs$, Et_2NH, and $PhNH_2$, respectively]. Attack on perfluoro-(2,6-dimethyl-1-azacyclohexene) by ammonia yielded the piperidine (IX), an analogue of the product (X) formed *via* addition of methanol across the C=N bond in derivative (IV).

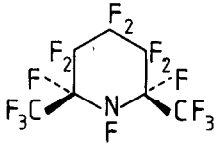
INTRODUCTION

Our long-standing interest in N-halogeno-compounds of the fluorocarbon class [2] originates from an encounter with perfluoro-N-fluoropiperidine whilst developing the first synthesis of pentafluoropyridine [3]. Study of the chemistry of this piperidine and of the related perfluoro-N-fluoromorpholine has proved fruitful, providing, for example, information about free radicals of the types $\overline{CF_2CF_2ZCF_2CF_2N}\cdot$ and $\overline{CF_2CF_2ZCF_2CF_2NO}\cdot$ (Z = CF_2 or O) [4], the anion $\overline{CF_2(CF_2)_4N}^-$ [5], and the NF-compounds as sources of 'positive' fluorine [6]. Throughout the work, the products of partial defluorination of the N-fluoro-compounds, *viz*. the cyclic imines $\overline{CF_2CF_2ZCF_2CF{=}N}$, have been encountered as by-products or intermediates, and investigations of their reactions with nucleophiles [7], electrophiles [8], and radicals [9] have followed naturally. Likewise, our current interest in α-substituted analogues of perfluoro-N-fluoropiperidine has led to the results now reported on nucleophilic displacement of fluorine from perfluoro-(2,6-dimethyl-1-azacyclohexene) (III), produced by partial defluorination of perfluoro-(N-fluoro-2,6-dimethylpiperidine) (I).

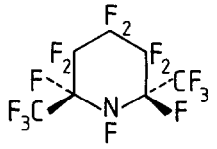
RESULTS AND DISCUSSION

Electrochemical Fluorination of 2,6-Dimethylpyridine

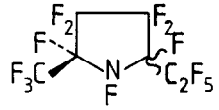
Perfluoro-(N-fluoro-2,6-dimethylpiperidine) was procured by Simons' electrochemical fluorination of 2,6-dimethylpyridine, a route developed by Davis, Haszeldine, and Tipping [10], who showed that the complex product contained three isomers of molecular formula $C_7F_{15}N$, the major one being perfluoro-[N-fluoro-2(e),6(e)-dimethylpiperidine] (I). The next most abundant isomer was presumed to be perfluoro-[N-fluoro-2(a),6(e)-dimethylpiperidine] (XI), and the third isomer was tentatively assigned structure (XII). More detailed ^{19}F n.m.r. studies during the present work have confirmed the assignment of structure (I) to the major isomer but, owing to separation difficulties, failed to clinch the structures of the other two. Additionally, a new product, perfluoro-(NN-difluoro-2-aminoheptane) $[CF_3CF(NF_2)CF_2CF_2CF_2CF_2CF_3]$(II), has been isolated and fully characterised spectroscopically (n.m.r. and mass); although the formation of acyclic material via C-N bond fission is a well known feature of the electrochemical fluorination of pyridines [see ref. 10 and lit. cited], this appears to be the first time that the ring-opened counterpart of a perfluoro-N-fluoropiperidine has been isolated.



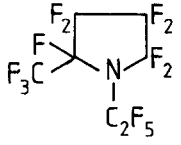
(I)



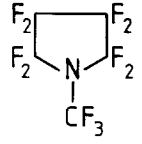
(XI)



(XII)



(XIII)

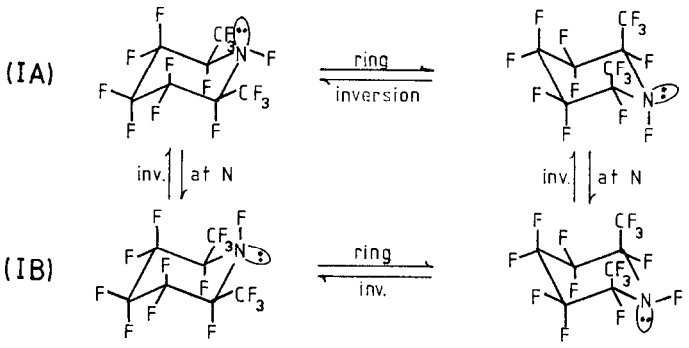


(XIV)

In order to obtain quickly a reasonable quantity of perfluoro-(N-fluoro-2,6-dimethylpiperidine), the batchwise electrochemical fluorination of 2,6-dimethylpyridine was carried out on fifty-times the original scale. Product boiling above room temperature was worked up by fractional distillation, NF-material being detected in distillate collected over the boiling range 81-100 °C (see the Experimental Section). Three fractions collected in the range 94-96 °C each contained >93% of the major $C_7F_{15}N$ isomer (I), the impurity being the compound thought to possess structure (XI); these fractions were combined and used to prepare perfluoro-(2,6-dimethyl-1-azacyclohexene) for the work described later.

^{19}F n.m.r. data for a g.l.c.-isolated sample of the major $C_7F_{15}N$ isomer was fully consistent with structure (I), *i.e.* perfluoro-(N-fluoro-*cis*-2,6-dimethylpiperidine). The spectrum comprised absorptions of the appropiate intensity at 4.0 (CF_3; positive values to low field of external CF_3CO_2H), -11.7 (NF), -45.0 and -55.6 (3,5-F, AB-type multiplet with ^2J = 295 Hz), -56.3 and -64.5 (4-F, AB-type multiplet with ^2J = 295 Hz), and -77.5 p.p.m. (>CF). When it was recorded at -10 °C, no change was observed except that the absorption at -77.5 p.p.m. changed from a triplet to a broad singlet. This suggests that one conformation is highly favoured but yields no information concerning the preferred disposition of the fluorine of the NF group (axial or equatorial). The results of a variable-temperature spin-echo n.m.r. study of perfluoro-N-fluoropiperidine have been interpreted in terms of rapid inversion at nitrogen, even at -115 °C [11]; assuming that inversion at nitrogen in perfluoro-(N-fluoro-*cis*-2,6-dimethylpiperidine) is fast on the n.m.r. time scale at 35.5 °C, and taking into account that the ring will probably be locked with the CF_3 groups occupying equatorial positions, then the spectrum will be a weighted average of invertomers (IA) and (IB). If ring inversion were occurring (see Scheme 1), it would have to be very rapid at -10 °C — an unlikely phenomenon according to work on polyfluorinated cyclohexanes [12]; furthermore, variable-temperature ^{19}F

n.m.r. studies on perfluoro-(N-fluoro-2-, -3-, and -4-methylpiperidine) have shown that the spectra are invariable over the range -90 to 100 °C, suggesting conformationally rigid structures with, presumably, the CF_3 group in each case lying in an equatorial position [13].



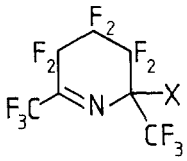
Scheme 1

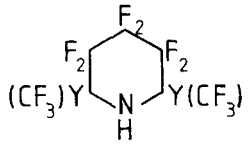
Attempts to isolate the minor $C_7F_{15}N$ component of the 94-96 °C fraction by g.l.c. failed. However, the ^{19}F n.m.r. spectrum of a sample of the major component (I) enriched in its contaminant by g.l.c. 'peak cutting' showed impurity bands at +3.6 (CF_3), -12.8 (NF), -45 to -57 (CF_2; 3 AB-type multiplets), and -77.2 (>CF) p.p.m. not inconsistent with the presence of perfluoro-(N-fluoro-trans-2,6-dimethylpiperidine) (XI); other impurity bands were also present, including one at -163 p.p.m. possibly caused by a CH_2F group, although a ^1H spectrum run at high gain in the δ 0-10 region was blank.

New information on the third $C_7F_{15}N$ isomer (present in distillation fractions collected in the boiling range 80-94 °C) is restricted to data gleaned from the ^{19}F n.m.r. spectrum of a mixture also containing perfluoro-n- and -iso-heptane (80:20) (ca. 5%), the cis-dimethylpiperidine (I) (ca. 75%), and the presumptive trans-isomer (XI) (ca. 10%). Importantly, no absorption assignable to an NF group other than those in (I) and (XI) was observed. This, coupled with the recent discovery [14] that traces of perfluoro-(N-methylpyrrolidine)

(XIV) are formed during electrochemical fluorination of pyridine, suggests that (XIII) is a more likely structure than (XII) for the third $C_7F_{15}N$ isomer.

Nucleophilic Attack on Perfluoro-(2,6-dimethyl-1-azacyclohexene) (III)

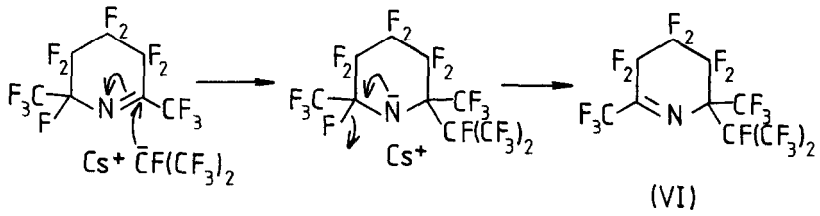




(III) X = F
(IV) X = OMe
(V) X = $ON(CF_3)_2$
(VI) X = $CF(CF_3)_2$
(VII) X = NEt_2
(VIII) X = NHPh

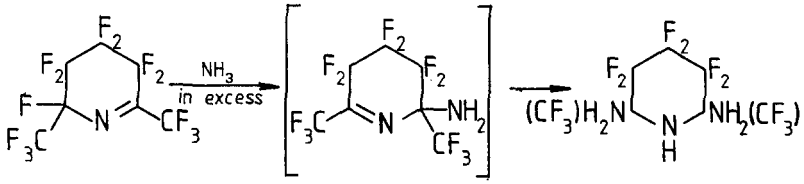
(IX) Y = NH_2
(X) Y = OMe

Perfluoro-(2,6-dimethyl-1-azacyclohexene) (III), a colourless, volatile (b.p. 72.5 °C) liquid was prepared in 91% yield by defluorination (Ph_3P in toluene [10]) of $C_7F_{15}N$ material containing >93% of perfluoro-[N-fluoro-2(e),6(e)-dimethylpiperidine] (I) [ECF cell product b.r. 94-96 °C (see above)]. It readily suffers nucleophilic attack by the appropiate carbon-, oxygen-, and nitrogen-centred nucleophiles to give derivatives (IV)-(VIII) (e.g. see Scheme 2), presumably via $S_N(AE)$ mechanisms analogous to those postulated for similar conversions involving perfluoro-1-azacyclohexene [7]. Unlike the situation [7] with its lower homologue, however, which contains three replaceable α-fluorines, the only complication encountered arose through simple nucleophilic addition of an excess of a reagent [e.g. $NH_3 \Rightarrow$(IX); see Scheme 3] or a solvent [e.g. (IV) + MeOH⇒(X)] across the C=N bond of a 6-substituted derivative formed first to give an isolable product.



(VI)

Scheme 2

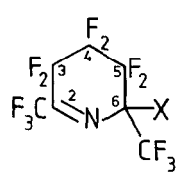


(III) (IX)

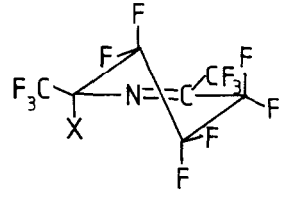
Scheme 3

^{19}F N.m.r. Spectra of 6-Substituted Perfluoro-(2,6-dimethyl-1-azacyclohexenes)

The 6-substituted perfluoro-(2,6-dimethyl-1-azacyclohexenes) [XV; X = F, OCH_3, $N(C_2H_5)_2$, NHPh, $ON(CF_3)_2$, or $CF(CF_3)_2$] all gave rise to ^{19}F n.m.r. spectra which showed



(XV)



(XVI)

two absorptions due to the CF_3 groups, one rather constant in position and fine structure (coupled to the adjacent CF_2 fluorine) assigned to the 2-CF_3 group and a more variable one assigned to the CF_3CX group (see the Table), and three overlapping AB-type multiplets due to the CF_2 groups. Apart from the perfluoroisopropyl-substituted compound which was exceptional and is discussed below, the spectra had a number of similarities. Also included is the chloro-substituted compound, obtained as a by-product from the reaction of the imine (III) with trimethylchlorosilane in the presence of caesium fluoride [15].

The allylic fluorines F-3 are expected to absorb to lowest field and to be least effected by the nature of the substituent X. Their assignment, apart from the perfluoro-isopropyl-substituted compound, then follows. This is further supported by the fact that the geminal F,F-coupling constant is approximately 320 Hz, which is distinctly greater than that observed for the remaining geminal pairs of fluorines, where an approximate range of 270-296 Hz is observed. The coupling constant, ^2J, is distinctly greater for the allylic fluorines in 1,2-dichlorooctafluoro- and decafluoro-cyclohexene [16]. A large ^2J of approximately 330 Hz is seen in one of the AB-multiplets of the perfluoroisopropyl-substituted compound, but in this case it is not the absorption to lowest field. Apart from this last compound, there is no great variation in the chemical shifts, and $\delta_A - \delta_B$ is large and relatively constant, with the diethylamino-compound somewhat exceptional.

Of the remaining pairs, F-4 should be least affected by X, and the AB-multiplet to highest field is so assigned, when the AB-multiplet showing the most variation is assigned to F-5.

Correlations within the individual chemical shifts were then sought. In perfluorocyclohexane the axial fluorines absorb 18.2 p.p.m. to low field of the equatorial fluorines [17]. The preferred conformation for cyclohexene is half-chair [18], and the parent azacyclohexene (XV; X = F) should adopt an analogous conformation with the bulky 6-CF_3 group

Table

^{19}F Chemical Shifts[a] of 6-Substituted Perfluoro-(2,6-Dimethyl-1-azacyclohexenes)

Substituent	2-CF_3	3-CF_2[b]	4-CF_2[b]	5-CF_2[b]	6-CF_3	Others
F[c]	6.8	-33.6 -50.8	-51.7 -69.2	-50.4 -55.6	-2.3	-68.6 (CFN)
OMe[c]	7.5	-33.1 -50.1	-50.2 -67.4	-47.3 -54.9	0.4	
Cl[c]	7.3	-31.3 -51.9	-45.8 -67.8	-45.7	1.8	
NHPh[c]	8.4	-31.5 -51.1	-46.7 -66.7	-46.1 -54.7	2.0	
$ON(CF_3)_2$[c]	6.7	-33.5 -51.3	-51.3 -68.3	-45.3 -52.7	2.3	10.2 9.7 (CF_3N)
NEt_2[c]	8.2	-35.0 -46.2	-47.3 -63.6	-42.2 -52.6	7.6	
$CF(CF_3)_2$[c]	6.5	-39.7 -46.7	-55.8 -61.2	-35.2 -38.8	13.2	7.9 (CF_3) -93.6 (CF)

[a] Positive values to low field of external CF_3CO_2H; [b] where two values are reported, an AB-type multiplet was observed; and [c] neat liquid.

occupying a less hindered quasi-equatorial position (XVI). The substantial similarities shown by all but the perfluoro-isopropyl-substituted compound, particularly for the chemical shifts of F-4 and to a lesser extent F-3, indicate a similar conformation to (XVI). In the Table, there are notable correlations of the chemical shift of the 6-CF_3 group with certain of the remaining chemical shifts (see the Figure). By analogy with perfluorocyclohexane, quasi-axial fluorines are assumed to absorb to low field of similar quasi-equatorial fluorines. The chemical shifts of 5-F_{ax} show a good linear correlation with those of 6-CF_3, an effect which is presumably through-bond in origin, whereas those of 5-F_{eq} show a poorer correlation, are less affected by the varying nature of X, and the second-row substituent chlorine is

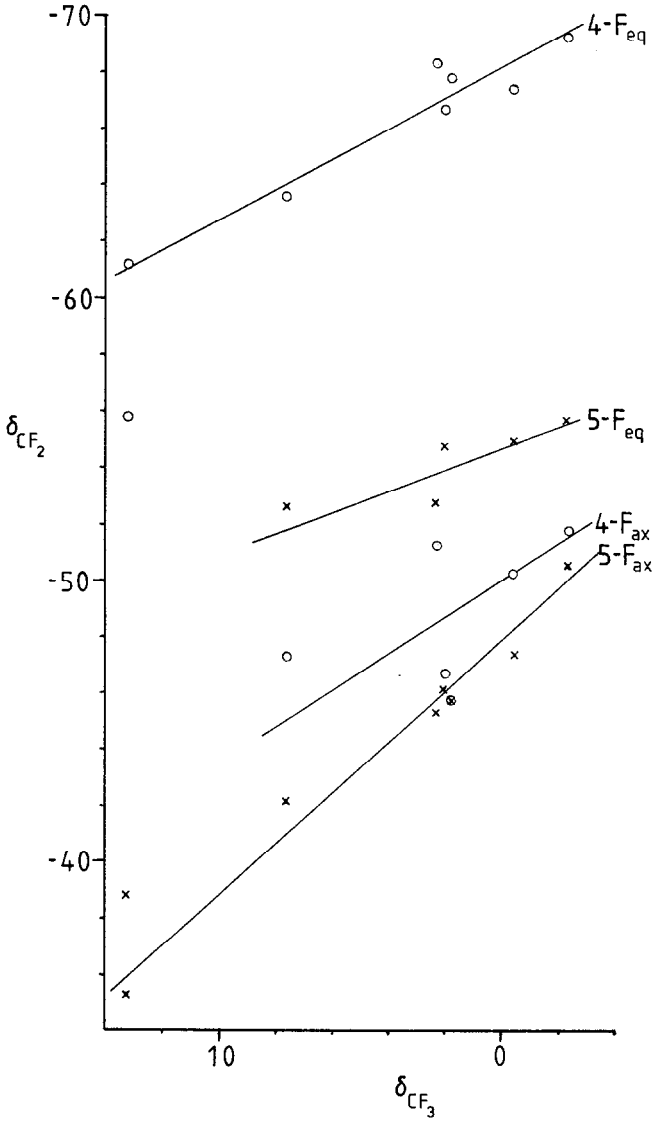


Figure Correlation of the 19-F chemical shifts of the 6-trifluoromethyl group with those of the difluoromethylene groups in 6-substituted perfluoro-(2,6-dimethyl-1-azacyclohexenes).

distinctly out of line, possibly as a result of a substantial electric field contribution [19]. The chemical shifts of 4-F_{ax} and 4-F_{eq} also show a linear correlation with those of 6-CF_3, the best fit occurring with the shifts of the quasi-equatorial fluorine; and the parallel trends indicate that there are no great axial-axial interactions.

In all this the perfluoroisopropyl-substituted compound stands out. The more bulky $CF(CF_3)_2$ group should occupy the quasi-equatorial position, rather than the CF_3 group. The 5-F_{eq} absorbs much to low field of expected, and this may reflect steric crowding [20] (large low-field shifts of a steric origin have been observed in fluoroalkyl-substituted pyridines [21]); in contrast, 4-F_{ax} absorbs much to high field of expected if the 6-CF_3 and -$CF(CF_3)_2$ were to have similar effects. Another effect may be operating in this compound. Steric congestion about C-6 can be relieved somewhat by flattening of the half-chair conformation, which would render the quasi-axial and -equatorial substituent environments more similar, which may account for the small chemical shift difference of the 3-fluorines, and of the remaining pairs of geminal fluorines.

The bistrifluoromethylamino-oxy-substituted azacyclohexene showed non-equivalent CF_3-groups of the $(CF_3)_2NO$-substituent at 33.5 °C, but their absorptions had coalesced to a single band at 100 °C. A similar non-equivalence has been reported for the CF_3 groups nearest to the asymmetric carbon in the compounds (XVII; X = F or Cl, Y = Z = H, or X = Z = F, Y = H) and interpreted in terms of restricted

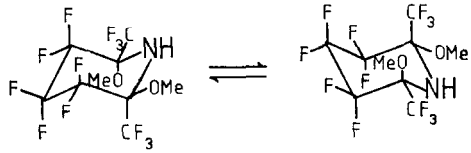
$$(CF_3)_2NOCXYCZ_2ON(CF_3)_2$$

(XVII)

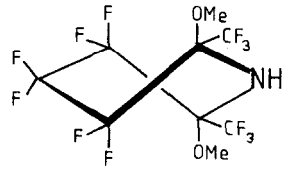
inversion at the nitrogen atom [22]. In the diethylamino-compound, the ethyl groups showed non-equivalent methylene group protons, as a result of the presence of an adjacent asymmetric carbon atom.

The diamino-derivative (IX) gave rise to a ^{19}F n.m.r. spectrum comprising absorptions at -2.2 (CF_3), -38.4 and

-62.2 (AB-type, 4-F, ^2J = 249 Hz), and -47.4 and -53.0 p.p.m. (AB-type, 3,5-F, ^2J = 271 Hz), which was consistent with it being the cis-isomer (cf. Scheme 1) having rapid proton exchange or inversion at the ring nitrogen [23]. In contrast, the dimethoxy-derivative (X) had a ^{19}F n.m.r. spectrum, invariant down to -30 °C, with absorptions at 3.5 (CF_3), -40.2 and -50.8 (AB-type, 3,5-F, ^2J = 256 Hz), and -45.8 p.p.m. (A_2-type, 4-F), which indicated that it was the trans-isomer. If the molecule adopts a chair conformation, then the spectrum requires rapid ring (and nitrogen) inversion:



or the molecule adopts some intermediate, twist conformation (XVIII) where effectively there is a C_2 axis through the N and C-4 atoms. The cis-isomer could not, except by accidental coincidence of chemical shifts, give rise to the observed simple spectrum. Only a few nitrogen containing six-membered rings have been shown to possess non-chair conformations [24].



(XVIII)

EXPERIMENTAL

Spectra

^{19}F N.m.r. and mass spectra were obtained with a Perkin-Elmer R32 instrument [84.6 MHz; ext. CF_3CO_2H ref., shifts to high field designated negative] and an A.E.I. MS/2H spectrometer (electron beam energy 70 eV).

Preparation of Perfluoro-[N-fluoro-2(e),6(e)-dimethylpiperidine]. A solution of 2,6-dimethylpyridine (5.12 kg) in anhydrous hydrogen fluoride (50 l) was electrolysed (6 V) in an apparatus of the type described previously [25] to give 9.42 kg of fluorocarbon product [1.44 kg collected in a cold trap (-78 °C) sited in the gas exit line, and 7.98 kg was drained from the base of the nickel cell]. A representative sample (2.00 kg) of the product was distilled through an adiabatic column (130 x 2.5 cm) packed with Pyrex Raschig rings (6 x 6 mm); eleven fractions spanning the boiling range 81-100 °C were collected, compound (I) being present in every one, together with either (XI) or (XIII) (tentative structure) or both; additionally, compound (II) was present in fractions boiling in the range 98-100 °C. Material (218 g) which distilled in the range 94-96 °C [three separate fractions were collected, but these varied little in composition (determined by g.l.c. using a 2 m Kel-F oil No. 10/Celite at 50 °C)] was found to be at least 93% perfluoro-[N-fluoro-2(e),6(e)-dimethylpiperidine] (Found: C, 22.2; F, 74.3; N, 3.3. Calc. for $C_7F_{15}N$: C, 21.9; F, 74.4; N, 3.65%), the contaminant being the isomer thought to be perfluoro-[N-fluoro-2(a),6(e)-dimethylpiperidine] [this mixture was used throughout to prepare perfluoro-(2,6-dimethyl-1-azacyclohexene)]. A fraction collected at 98-100 °C (38 g) was subjected to preparative g.l.c. (4 m Kel-F No. 10 oil/Celite, 60 °C) to provide perfluoro-(NN-difluoro-2-aminoheptane) (nc) (Found: C, 20.1; F, 77.0; N, 3.3. $C_7F_{17}N$ requires C, 19.95; F, 76.7; N, 3.3%), b.p. 103.5 °C at 767.5 mmHg (Siwoloboff), δ_F (neat liq.) +97.6 (NF_2), +6.2

[$C\underline{F}_3CF(NF_2)$], -4.7 [$C\underline{F}_3(CF_2)_4$], -39.3 [$CF_3CF(NF_2)C\underline{F}_2$], -43.5 and -45.3 ($CF_3CF_2C\underline{F}_2C\underline{F}_2$), -49.2 ($CF_3C\underline{F}_2$) and -86.2 [$CF_3C\underline{F}(NF_2)$] p.p.m. (all peaks broad; no coupling resolved), and m/e 364 [$C_7F_{14}N^+$; 1% (top mass peak)], 345 ($C_7F_{13}N^+$; 1%), 281 ($C_6F_{11}^+$; 1%), 231 ($C_5F_9^+$; 3%), 181 ($C_4F_7^+$; 13%), 164 ($C_3F_6N^+$; 4%), 150 ($C_3F_6^+$; 2%), 145 ($C_3F_5N^+$; 2%), 131 ($C_3F_5^+$; 30%), 100 ($C_2F_4^+$; 12%), 50 (CF_2^+; 3%), 31 (CF^+; 6%), and 269, 219, 169, 119, and 69 [$(C_nF_{2n+1})^+$; n = 1 (100%), 2 (45%), 3 (19%), 4 (6%), and 5 (1%)].

Reactions of Perfluoro-(2,6-dimethyl-1-azacyclohexene)

Perfluoro-(2,6-dimethyl-1-azacyclohexene) was prepared by Oppenheim's method (see ref. 10).

(a) With sodium methoxide

Perfluoro-(2,6-dimethyl-1-azacyclohexene) (28.75 g, 83.33 mmol) was condensed, in vacuo, into a cold (-196 °C) Pyrex ampoule (300 cm^3) containing petroleum ether (b.p. 40-60 °C; 25 cm^3) and sodium methoxide (4.50 g, 83.3 mmol); the tube was sealed whilst evacuated and shaken at room temperature for 4 days. Distillation of the volatile product by trap-to-trap fractional condensation in vacuo provided 3,3,4,4,5,5-hexafluoro-6-methoxy-2,6-bis(trifluoromethyl)-1-azacyclohexene (nc) (20.4 g, 57.1 mmol, 68.5%) (Found: C, 26.9; H, 0.7: F, 63.6: N, 3.7. $C_8H_3F_{12}NO$ requires C, 26.9; H, 0.8; F, 63.9; N, 3.9%), b.p. 112 °C (Siwoloboff) $\lambda_{max.}$ (vapour) 1713 cm^{-1} (C=N str.) (this product condensed in the -23 and -45 °C traps), δ_H -3.85 p.p.m. (s, ext. p-$C_6H_4Cl_2$ ref.).

(b) With NN-bistrifluoromethylhydroxylamine-caesium fluoride

The hydroxylamine (1.2 g, 7.1 mmol) [CARE: this compound (b.p. 32.5 °C) is a powerful anaesthetic] was condensed, in vacuo, onto caesium fluoride (1.9 g, 12.5 mmol) (previously dried in situ at 150 °C for 3 h under vacuum) contained in a cold (-196 °C) Pyrex tube (120 cm^3) fitted with a PTFE

needle valve; the tube was sealed, shaken at room temperature for 1.5 h, re-cooled to -196 °C, then re-opened (still *in vacuo*) to admit perfluoro-(2,6-dimethyl-1-azacyclohexene) (2.53 g, 7.33 mmol). The valve was closed and the tube was shaken vigorously at room temperature for 5 h. Work-up of the volatile product by trap-to-trap fractional condensation *in vacuo*, followed by analysis [i.r. and g.l.c. (2 m Kel-F No. 10 oil/Celite, 80 °C)] of the fractions, revealed the presence of NN-bistrifluoromethylhydroxylamine (traces), perfluoro-(2,6-dimethyl-1-azacyclohexene) (0.55 g, 1.59 mmol, 22% recovery), and 3,3,4,4,5,5-hexafluoro-2,6-bis(trifluoromethyl)-6-(bistrifluoromethylamino-oxy)-1-azacyclohexene (nc) (2.64 g, 5.34 mmol, 93% based on $C_7F_{13}N$ consumed); an almost pure sample (0.78 g, >98% by g.l.c.) (Found: C, 21.6; F, 69.7; N, 5.9. $C_9F_{18}N_2O$ requires C, 21.9; F, 69.2; N, 5.7%), $\lambda_{max.}$ (vapour) 1715 cm^{-1} (C=N str.), of the last component was recovered from the 20 °C trap.

(c) With perfluoroisopropylcaesium

A mixture of perfluoro-(2,6-dimethyl-1-azacyclohexene) (3.19 g, 9.25 mmol), perfluoropropene (3.24 g, 21.6 mmol), and anhydrous caesium fluoride (*ca.* 6 g) was heated in the absence of air at 245 °C for 2 days in a monel autoclave (50 cm^3). Work-up of the volatile product by a combination of trap-to-trap fractional condensation and g.l.c. (10 m SE30, 90 °C) provided perfluoro-(6-isopropyl-2,6-dimethyl-1-azacyclohexene) (nc) (1.30 g, 2.63 mmol, 50% based on $C_7F_{13}N$ consumed) (Found: C, 24.2; F, 73.3; N, 2.6. $C_{10}F_{19}N$ requires C, 24.2; F, 72.9; N, 2.8%), $\lambda_{max.}$ (vapour) 1725 cm^{-1} (C=N str.), perfluoro-(2,6-dimethyl-1-azacyclohexene) (1.39 g, 4.03 mmol, 44% recovery), and perfluoro-(4-methylpent-2-ene) (0.62g, 2.07 mmol) ('C_3F_6 dimer', identified by i.r. spectroscopy).

(d) With ammonia

Perfluoro-(2,6-dimethyl-1-azacyclohexene) (3.14 g, 9.10 mmol) and ammonia (0.308 g, 18.1 mmol) were condensed

separately into a cold (-196 °C), evacuated Pyrex ampoule (300 cm^3). The ampoule was sealed and allowed to warm slowly to 0 °C, and then to room temperature. Volatile material was pumped out of the ampoule, leaving a solid orange residue which was washed out of the ampoule with diethyl ether. The washings were filtered (to remove insoluble brown material, shown by i.r. spectroscopy to contain much ammonium fluoride) then evaporated to provide off-white perfluoro-(2,6-diamino-2,6-dimethylpiperidine) (nc) (1.82 g, 5.07 mmol, 84% based on NH_3) (Found: C, 23.7; H, 1.3; F, 63.7; N, 11.4. $C_7H_5F_{12}N_3$ requires C, 23.4; H, 1.4; F, 63.5; N, 11.7%), m.p. 88-90 °C, $\lambda_{max.}$ (mull) 3410, 3390 (br. d, barely resolved), 3375 (sh.), 3300, 3270 (br. sh.), and 3190 cm^{-1} (v. br.) (N-H str.), δ_H [$(CD_3)_2CO$ soln.; ext. p-$C_6H_4Cl_2$] -4.0 (br., NH) and -4.5 p.p.m. (br., NH_2).

(e) With diethylamine (with C. OPPENHEIM)

A reaction occurred immediately (with precipitation of diethylammonium fluoride) when perfluoro-(2,6-dimethyl-1-azacyclohexene) (4.00 g, 11.6 mmol) was added slowly to a solution of diethylamine (1.60 g, 21.9 mmol) in diethyl ether (11 cm^3). The mixture was shaken for 16 h then filtered; distillation of the filtrate gave 6-diethylamino-3,3,4,4,5,5-hexafluoro-2,6-bis(trifluoromethyl)-1-azacyclohexene (nc) (2.20 g, 5.52 mmol, 48%) [Found: C, 33.0; H, 2.6; F, 56.9; N, 7.0%; M (mass spec.), 398. $C_{11}H_{10}F_{12}N_2$ requires C, 33.2; H, 2.5; F, 57.3; N, 7.0%; M, 398], b.p. 62 °C at 10 mmHg, $\lambda_{max.}$ (film) 1713 cm^{-1} (C=N str.), δ_H 3.05 (CH_2, AB-type multiplet, δ_{AB} 0.211 p.p.m., J_{AB} = 19.0 Hz; $SiMe_4$ ref.) and 1.08 p.p.m. (CH_3, t, ^3J = 6.9 Hz).

(f) With aniline

A white solid (shown later by n.m.r. spectroscopy to be anilinium fluoride) appeared immediately and the liquid phase turned crimson when a solution of perfluoro-(2,6-dimethyl-1-azacyclohexene) (2.16 g, 6.26 mmol) in dry ether (5 cm^3) was added dropwise (15 min) to a stirred solution of aniline (1.20 g, 12.9 mmol) in the same solvent (5 cm^3). The mixture was stirred for 20 h then filtered to remove

anilinium fluoride. Distillation of the filtrate provided a pale yellow oil, b.p. 42-46 °C at <1 mmHg, shown by g.l.c. to contain two components. Attempts to separate the major of these (>80%) by preparative g.l.c. (2 m SE30, 190 °C) provided only an impure sample of oily 3,3,4,4,5,5-hexafluoro-6-phenylamino-2,6-bis(trifluoromethyl)-1-azacyclohexene (1.45 g, ca. 55%) (Found: C, 39.8; H, 1.9; F, 50.8; N, 7.1. Calc. for $C_{13}H_6F_{12}N_2$: C, 37.3; H, 1.4; F, 54.5; N, 6.7%) which was identified by n.m.r. spectroscopy and mass spectrometry [m/e 418 (M^+, 63%), 349 ($M^+-CF_3\cdot$, 100%), 93 ($C_6H_5NH_2^+$, 62%), 92 ($C_6H_5NH^+$, 23%), 77 ($C_6H_5^+$, 98%)].

Reaction of 3,3,4,4,5,5-Hexafluoro-6-methoxy-2,6-bis(trifluoromethyl)-1-azacyclohexene with Methanol

An excess of methanol (ca. 2 g, ca. 60 mmol) and the monomethoxy-compound (8.40 g, 23.5 mmol) were condensed separately into a cold (-196 °C), evacuated, Pyrex ampoule (300 cm^3) which was then sealed and shaken at room temperature for 2 days. Volatile material was then pumped out of the tube and immediately separated into methanol and 3,3,4,4,5,5-hexafluoro-6-methoxy-2,6-bis(trifluoromethyl)-1-azacyclohexene (3.20 g, 8.9 mmol, 38% recovery) (-23 °C trap) by trap-to-trap fractional condensation in vacuo; the white solid left behind was washed out with 1,1,2-trichlorotrifluoroethane, recovered by evaporation techniques, and shown by n.m.r. spectroscopy to be 3,3,4,4,5,5-hexafluoro-2,6-dimethoxy-2,6-bis(trifluoromethyl)piperidine (4.80 g, 12.3 mmol, 85% based on starting material consumed) (Found: C, 27.9; H, 1.8: F, 58.2; N, 3.6. $C_9H_7F_{12}NO_2$ requires C, 27.7; H, 1.8; F, 58.6; N, 3.6%), m.p. 34-36 °C, $\lambda_{max.}$ (mull) 3448 cm^{-1} (N-H str.), δ_H ($CDCl_3$ soln., ext. p-$C_6H_4Cl_2$ ref.) -3.45 (br., NH) and -3.75 p.p.m. (s, OCH_3).

REFERENCES

1 Part II, R.E. Banks and S.M. Hitchen, J. Fluorine Chem., 12 (1978) 159.

2 See R.E. Banks, P.A. Carson, and R.N. Haszeldine, J. Chem. Soc. Perkin Trans. I, (1973) 111, and previous parts in that series.

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

4 R.E. Banks, K. Mullen, and G.E. Williamson, J. Chem. Soc. (C), (1968) 2608; R.E. Banks, K. Mullen, W.J. Nicholson, C. Oppenheim, and A. Prakash, J. Chem. Soc. Perkin Trans. I, (1972) 1098; R.E. Banks, A.J. Parker, M.J. Sharp, and G.F. Smith, J. Chem. Soc. Perkin Trans. I, (1973) 5.

5 A.R. Bailey, R.E. Banks, M.G. Barlow, and M. Nickkho-Amiry, publication in preparation.

6 R.E. Banks and G.E. Williamson, Chem. and Ind., (1964) 1864; R.E. Banks, R.N. Haszeldine, and R. Hatton, Tetrahedron Letters, (1967) 3993; R.E. Banks, A.J. Parker, M.J. Sharp, and G.F. Smith, J. Chem. Soc. Perkin Trans. I, (1973) 5; A.R. Bailey, R.E. Banks, E.D. Burling, and R. Hatton, researches still in progress.

7 R.E. Banks and C. Oppenheim, J. Fluorine Chem., 12 (1978) 27.

8 R.E. Banks and C. Oppenheim, unpublished results.

9 R.E. Banks, W.M. Cheng, R.N. Haszeldine, and G. Shaw, J. Chem. Soc. (C), (1970) 55.

10 V.J. Davis, R.N. Haszeldine, and A.E. Tipping, J. Chem. Soc. Perkin Trans. I, (1975) 1263. The claim [R.N. Haszeldine, J. Chem. Soc., (1950) 1638] regarding the synthesis of perfluoro-(N-fluoro-2,6-dimethylpiperidine) by F_2- or CoF_3-fluorination of 2,6-lutidine was withdrawn by the originator almost immediately [see R.N. Haszeldine, J. Chem. Soc., (1951) 102], a point not noticed by most reviewers.

11 L.W. Reeves and E.J. Wells, Discuss. Faraday Soc., 34 (1962) 177.

12 J. Honier and L.F. Thomas, Trans. Faraday Soc., 59 (1963) 2431; A Peake and L.F. Thomas, ibid., 62 (1966) 2980.

13 J. Lee and K.G. Orrell, Trans. Faraday Soc., 63 (1967) 16.

14 A.R. Bailey, R.E. Banks, and M.G. Barlow, unpublished results.

15 R.E. Banks, M.G. Barlow, and M. Nickkho-Amiry, unpublished results.

16 J.E. Anderson and J.D. Roberts, J. Amer. Chem. Soc., 92 (1970) 97.

17 G.V.D. Tiers, Proc. Chem. Soc., (1960) 391; for a recent rate determination see J. Burdon, J.C. Hotchkiss, and W.B. Jennings, Tetrahedron, 33 (1977) 1745.

18 E.L. Eliel, N.L. Allinger, S.J. Angyal, and G.A. Morrison, 'Conformational Analysis', Interscience Publishers, New York, N. Y., 1965, p. 109; M. Hanack, 'Conformational Theory', Academic Press, New York, N. Y., 1965, p. 147.

19 J.W. Emsley and L. Phillips, "Progress in Nuclear Magnetic Resonance Spectroscopy", vol. 7, edit. J.W. Emsley, J. Feeney, and L.H. Sutcliffe, Pergamon Press, Oxford, 1971, p. 94.

20 N. Boden, J.W. Emsley, J. Feeney, and L.H. Sutcliffe, Mol. Phys., 8 (1964) 467; G.L. Caldow, ibid., 11 (1966) 71.

21 R.S. Matthews, J. Magnetic Resonance, 30 (1978) 537.

22 M.G. Barlow and K.W. Cheung, J. Fluorine Chem., 12 (1978) 35.

23 Nitrogen inversion in piperidine can only be detected if precautions are taken to avoid axchange: F.A.L. Anet and I. Yavari, J. Amer Chem. Soc., 99 (1977) 2794.

24 G.M. Kelli and F.G. Riddell, 'Topics in Stereochemistry', vol. 8, p. 225, E.L. Eliel and N.L. Allinger, edit., Interscience, New York, N. Y., 1974; for a recent example see S. Tsuboyama, J. Uzawa, R. Koda, M. Nakamaru, K. Kobayashi, and T. Sakurai, Tetrahedron Letters, (1977) 2895.

25 R.N. Haszeldine and F. Nyman, J. Chem. Soc., (1956) 2684.