Crystal and Molecular Structure of the Major Products from the Benzylation of 1-Ethyl-4-phenylpiperidine and 1-Isopropyl-4-phenylpiperidine[1]

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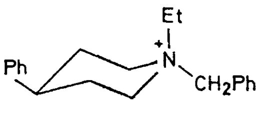
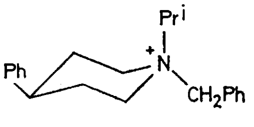
The structures of the major isomers of 1-benzyl-1-ethyl- (1) and of 1-benzyl-1-isopropyl-4-phenylpiperidinium chloride (2), as determined by *X*-ray analysis, indicate that *N*-benzylation of piperidines normally occurs by preferential equatorial attack. Crystals of (1) are orthorhombic, space group *Pbca*, with Z = 8 in a unit-cell of dimensions: a = 9·41(3), b = 17·94(6), c = 20·47(6) Å. Crystals of (2) are monoclinic, space group *C*2/*c*, with Z = 8 in a unit-cell of dimensions a = 27·778(19), b = 9·483(7), c = 19·911(12) Å, β = 133·05(2)°. The structures were solved by the symbolic addition procedure and refined by block-diagonal least-squares methods to R 0·13 [(1), 2036 photographic data] and 0·048 [(2), 2089 diffractometer data].

THE *N*-quaternization of *N*-substituted piperidines yields two alternative products which derive from attack by the quaternizing agent at the axial or equatorial position. This and the preceding paper[2] are concerned with the steric course of *N*-benzylation of piperidines. We now report the crystal structure analysis of the two major isomers [(1) and (2)] from the reactions of 1-ethyl-4-phenylpiperidine and 1-isopropyl-4-phenylpiperidine with benzyl chloride.



(1)



(2)

EXPERIMENTAL

Suitable single crystals of the major quaternization products of the ethyl and isopropyl derivatives were obtained by slow evaporation of an acetonitrile solution at room temperature.

Crystal Data and Intensity Measurements.—Ethyl derivative, (1). $C_{20}H_{26}ClN$, M = 315·9. Orthorhombic, a = 9·41(3), b = 17·94(6), c = 20·47(6) Å, U = 3455·6 Å^3, D_c = 1·21, Z = 8, $F(000)$ = 1360. Space group *Pbca* (D_{2h}^{15}) from systematic absences. Cu-K_α radiation, λ = 1·5418 Å, μ(Cu-K_α) = 19·1 cm^{-1}. Unit-cell dimensions and space group were determined from oscillation and Weissenberg photographs. Errors quoted for cell dimensions are maximum. No density measurement was performed, owing to the limited amount of material available. Intensity data were collected by the equi-inclination Weissenberg technique, with nickel-filtered Cu-K_α radiation. Two different crystals were used and eight layers (0—7kl) of reflections were collected around the a axis of the first crystal and eleven (h0—10l) around the b axis of the other crystal. Altogether, 2036 independent non-zero reflections were estimated visually and used in the final refinement. Corrections for Lorentz, polarization, and spot-extension[3] were applied, and inter-layer scaling,[4] but not those for absorption nor extinction.

Isopropyl derivative, (2). $C_{21}H_{28}ClN,H_2O$, M = 347·9. Monoclinic, a = 27·778(19), b = 9·483(7), c = 19·911(12) Å, β = 133·05(2)°, U = 3833·0 Å^3, D_c, = 1·205, Z = 8, $F(000)$ = 1504. Space group *Cc* (C_s^4) or *C*2/*c* (C_{2h}^6) from systematic absences, shown to be *C*2/*c* from structure analysis. Mo-K_α radiation, λ = 0·7107 Å, μ(Mo-K_α) = 2·1 cm^{-1}. Unit-cell dimensions and their estimated standard deviations (in parentheses) were determined by a least-squares fit to the 2θ values of twenty-six high-angle reflections measured on an A.E.D. Siemens automatic single-crystal diffractometer. No density measurement was performed, owing to the limited amount of material available.

Intensity data were collected by the same diffractometer, by use of zirconium-filtered Mo-K_α radiation, by the moving-crystal–stationary-detector (ω-scan) technique. The crystal used for data collection was mounted along the c axis. Each reflection was scanned twice with stationary-crystal–stationary-counter background counts taken at each end for a time equal to the scan time. The scan range for each reflection was 1·60°. Three standard reflections were checked regularly during collection and these showed no significant changes. 3198 Independent reflections, up to a limit θ value of 28·0° were measured, and 2089 of these had significant intensity having $I > 3\sigma(I)$. Absorption and extinction corrections were not applied.

Determination and Refinement of the Structures.—Both structures were solved by the symbolic-addition procedure.[5] The overall temperature and scale factors obtained from the usual Wilson plot, were used to calculate the normalized structure factors, E values, from the observed structure factors. The two sets of phases were determined by a program written by one of us (J. R. C.).

Ethyl derivative, (1). An E-map computed by use of the phases of only 162 of the highest E values showed unambiguously all the non-hydrogen atom positions. The structure-model was first refined by least-squares, with all the atoms being assigned individual isotropic temperature factors. Successive anisotropic refinement was achieved in the semi-diagonal approximation of two blocks, one including the positional parameters, the other the scale factor and the thermal parameters. The hydrogen atom positions could not be determined from the final difference-Fourier map. The final R for all reflections was 0·13. The weighting function used throughout the refinement was $w = 1/(1 + F_o/b)$ with b = 1·42.

Isopropyl derivative, (2). The E map computed by use of 271 of the highest E values again showed the complete structure. This was refined by least-squares, with indi-

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[1] Preliminary communication, R. P. Duke, R. A. Y. Jones, A. R. Katritzky, J. R. Carruthers, W. Fedeli, F. Mazza, and A. Vaciago, *J.C.S. Chem. Comm.*, 1972, 455.

[2] R. P. Duke, R. A. Y. Jones, and A. R. Katritzky, preceding paper.

[3] D. C. Phillips, *Acta Cryst.*, 1954, **7**, 746.

[4] W. C. Hamilton, J. S. Rollett, and R. A. Sparks, *Acta Cryst.*, 1965, **18**, 129.

[5] J. Karle and I. L. Karle, *Acta Cryst.*, 1966, **21**, 849.

vidual isotropic temperature factors assigned to all atoms. A difference-Fourier synthesis showed a significant high electron-density peak, not at a bonding distance from any located atomic position: this was interpreted as belonging to the oxygen of a water molecule. A further difference electron-density map computed after three cycles of anisotropic least-squares refinement made it possible to locate all the thirty hydrogen atom positions. The least-squares refinement was then completed in the semi-diagonal approximation of two blocks, one including the positional parameters, the other the scale factor and the temperature factors (anisotropic for the heavy atoms, isotropic for the hydrogen atoms) and gave a final R of 0·048 for all reflections. The weighting function used throughout the refinement was $w = 1/\sigma(F)$.

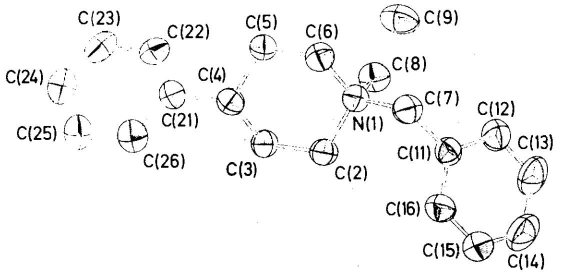

FIGURE 1 ORTEP plot of the thermal ellipsoids of the non-hydrogen atoms of the 1-benzyl-1-ethyl-4-phenylpiperidinium ion, at the 50% probability level and showing the atom numbering system used

Calculations.—The least-squares program minimizes the function $\Sigma w(|F_o| - |F_c|)^2$ and refinement was ended at convergence of the sum of the squares of the ratios between the calculated shifts and the estimated standard deviations of the parameters. Atomic scattering factors for oxygen, nitrogen, and carbon atoms were taken from ref. 6 and for hydrogen from ref. 7. Calculations were carried out on the UNIVAC 1108 computer of Rome University, using the program library[8] of the Laboratorio di Strutturistica Chimica 'Giordano Giacomello'. The illustrations (Figures 1 and 2) of the thermal vibration ellipsoids were produced by the ORTEP program.[9] Observed and calculated structure factors are published in Supplementary Publication No. SUP 20743 (7 pp.).*

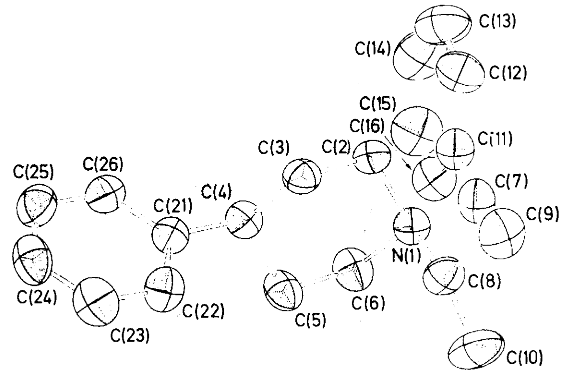

FIGURE 2 ORTEP plot of the thermal ellipsoids of the non-hydrogen atoms of the 1-benzyl-1-isopropyl-4-phenylpiperidinium ion, at the 50% probability level, and showing the atom numbering system used

TABLE 1

Final positional and anisotropic temperature parameters for non-hydrogen atoms in (1) with estimated standard deviations in parentheses *

	x	y	z	b_{11}	b_{12}	b_{13}	b_{22}	b_{23}	b_{33}
Cl	0·2905(3)	0·3341(2)	0·5659(2)	140(3)	40(3)	−28(3)	61(1)	−64(2)	59(1)
N(1)	0·2462(6)	0·1405(3)	0·4713(3)	93(6)	12(6)	1(5)	25(2)	−1(3)	22(1)
C(2)	0·3988(7)	0·1614(4)	0·4861(4)	97(9)	3(7)	−6(6)	26(2)	9(3)	29(2)
C(3)	0·4722(7)	0·1064(4)	0·5339(3)	99(8)	10(7)	−3(6)	25(2)	5(3)	25(2)
C(4)	0·3852(7)	0·0966(4)	0·5961(3)	95(8)	2(7)	−1(6)	29(2)	−4(3)	23(2)
C(5)	0·2351(7)	0·0709(4)	0·5784(3)	90(8)	−7(8)	2(6)	38(3)	6(3)	22(2)
C(6)	0·1647(8)	0·1286(4)	0·5343(3)	110(9)	10(8)	13(6)	35(3)	−5(3)	21(2)
C(7)	0·1713(8)	0·2081(4)	0·4377(4)	106(9)	14(8)	3(7)	31(3)	3(4)	29(2)
C(8)	0·2460(9)	0·0724(4)	0·4269(3)	134(10)	−6(8)	5(7)	27(2)	−12(3)	26(2)
C(9)	0·1022(10)	0·0364(5)	0·4146(5)	146(12)	−41(11)	10(9)	43(3)	−17(5)	37(3)
C(11)	0·2382(8)	0·2323(4)	0·3752(4)	120(9)	−3(8)	−21(7)	26(2)	4(3)	26(2)
C(12)	0·1887(9)	0·2062(5)	0·3153(4)	153(11)	−14(10)	−18(8)	39(3)	2(4)	25(2)
C(13)	0·2530(11)	0·2307(5)	0·2584(4)	226(15)	7(12)	−23(10)	32(3)	14(4)	30(2)
C(14)	0·3653(10)	0·2817(6)	0·2603(5)	162(13)	24(13)	11(10)	51(4)	38(6)	39(3)
C(15)	0·4060(10)	0·3095(6)	0·3191(5)	148(12)	−46(12)	−29(10)	56(4)	35(6)	40(3)
C(16)	0·3480(9)	0·2857(5)	0·3757(4)	133(10)	−35(10)	−33(9)	38(3)	17(5)	37(3)
C(21)	0·4592(7)	0·0456(4)	0·6441(3)	105(8)	9(8)	−5(6)	27(2)	−8(3)	20(2)
C(22)	0·4252(8)	−0·0288(4)	0·6546(4)	130(10)	−10(8)	13(7)	28(2)	2(3)	25(2)
C(23)	0·4944(9)	−0·0710(5)	0·7008(4)	163(12)	8(10)	25(9)	35(3)	14(4)	30(2)
C(24)	0·6016(10)	−0·0404(5)	0·7382(4)	173(12)	20(11)	−5(8)	42(3)	6(4)	25(2)
C(25)	0·6445(10)	0·0322(5)	0·7270(4)	164(12)	18(10)	−16(8)	37(3)	−2(4)	26(2)
C(26)	0·5730(9)	0·0747(4)	0·6807(4)	157(11)	12(9)	−16(8)	28(2)	−10(4)	28(2)

* The coefficients b_{ij} are defined by the expression: $T = \exp[-10^{-4}(b_{11}h^2 + b_{22}k^2 + b_{33}l^2 + b_{12}hk + b_{13}hl + b_{33}kl)]$.

RESULTS AND DISCUSSION

Molecular Configuration.—The two compounds possess several features in common and these will be discussed together. The unit cells of both derivatives contain eight asymmetric units, which consist of one molecule of *N*-benzyl-*N*-ethyl-4-phenylpiperidinium chloride for the

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* For details see Notice to Authors No. 7 in *J.C.S. Dalton*, 1972, Index issue.

[6] D. T. Cromer and J. B. Mann, *Acta Cryst.*, 1968, **24**, 321.

[7] H. P. Hanson, F. Herman, J. D. Lea, and S. Skillman, *Acta Cryst.*, 1964, **17**, 1040.

[8] A. Domenicano, R. Spagna, and A. Vaciago, *Atti Accad. naz. Lincei, Rend. Classe Sci. fis. mat. nat.*, 1969, **47**, 331.

[9] C. K. Johnson, 'ORTEP: A Fortran Thermal Ellipsoid Plot Program for Crystal Structure Illustrations,' Oak Ridge National Laboratory Report ORNL 3794, 1965.

TABLE 2

Final positional and anisotropic temperature parameters for the non-hydrogen atoms in (2) with estimated standard deviations in parentheses *

	x	y	z	b_{11}	b_{12}	b_{13}	b_{22}	b_{23}	b_{33}
Cl	0·2439(0)	0·3146(1)	0·1230(0)	32(0)	−15(1)	65(1)	156(1)	−14(1)	62(0)
O	0·3106(2)	0·0955(3)	0·0753(2)	50(1)	82(3)	81(2)	225(4)	68(4)	69(2)
N(1)	0·1778(1)	0·2471(2)	0·2872(1)	21(1)	1(2)	43(1)	105(3)	1(3)	43(1)
C(2)	0·1445(1)	0·1172(3)	0·2270(2)	22(1)	−10(2)	41(2)	92(3)	4(3)	48(1)
C(3)	0·1133(1)	0·1422(3)	0·1296(2)	22(1)	3(2)	44(2)	87(3)	−3(3)	47(1)
C(4)	0·0617(1)	0·2599(3)	0·0846(2)	21(1)	7(2)	44(2)	102(3)	4(3)	45(1)
C(5)	0·0956(2)	0·3916(3)	0·1433(2)	31(1)	31(3)	51(2)	97(3)	13(3)	46(1)
C(6)	0·1265(2)	0·3636(3)	0·2406(2)	29(1)	28(3)	54(2)	117(4)	6(4)	49(1)
C(7)	0·2017(2)	0·2171(4)	0·3816(2)	23(1)	1(3)	46(2)	161(4)	15(4)	44(1)
C(8)	0·2372(2)	0·2894(3)	0·3002(2)	25(1)	−22(3)	56(2)	130(4)	−8(4)	53(1)
C(9)	0·2888(2)	0·1742(5)	0·3459(3)	25(1)	9(4)	67(3)	202(6)	18(5)	75(2)
C(10)	0·2677(2)	0·4269(4)	0·3510(3)	46(1)	−73(4)	98(3)	158(5)	−54(6)	88(2)
C(11)	0·1501(1)	0·1689(3)	0·3817(2)	23(1)	0(3)	47(2)	138(4)	9(4)	45(1)
C(12)	0·1394(2)	0·0274(3)	0·3818(2)	37(1)	7(3)	83(2)	133(4)	23(4)	70(2)
C(13)	0·0936(2)	−0·0175(4)	0·3846(3)	50(1)	−49(4)	104(3)	151(5)	−25(5)	88(2)
C(14)	0·0581(2)	0·0802(5)	0·3867(3)	35(1)	−39(4)	91(3)	231(6)	−22(6)	89(2)
C(15)	0·0694(2)	0·2205(4)	0·3889(3)	35(1)	6(4)	89(3)	189(6)	6(5)	85(2)
C(16)	0·1153(2)	0·2655(4)	0·3865(2)	31(1)	−1(3)	65(2)	147(4)	−2(4)	56(2)
C(21)	0·0258(1)	0·2811(3)	−0·0149(2)	21(1)	9(2)	43(2)	91(3)	−4(3)	44(1)
C(22)	0·0541(2)	0·3441(3)	−0·0431(2)	23(1)	2(3)	50(2)	156(4)	−5(4)	52(1)
C(23)	0·0195(2)	0·3623(4)	−0·1346(2)	38(1)	15(4)	74(3)	175(5)	13(5)	58(2)
C(24)	−0·0444(2)	0·3151(4)	−0·2003(2)	35(1)	30(3)	50(2)	156(4)	−1(4)	43(1)
C(25)	−0·0734(2)	0·2516(3)	−0·1747(2)	27(1)	−2(3)	40(2)	120(4)	−27(4)	52(2)
C(26)	−0·0388(1)	0·2358(3)	−0·0825(2)	24(1)	−5(3)	47(2)	106(3)	−11(4)	51(1)

* See footnote to Table 1.

ethyl derivative, and one molecule of *N*-benzyl-*N*-isopropyl-4-phenylpiperidinium chloride together with one water molecule for the isopropyl derivative. The refined atomic parameters and their estimated standard deviations, as obtained from the least-squares refinement, are given in Tables **1**—**3**. Bond distances and angles are listed in Tables 4—6 and details of planes are in Tables 7 and 8. The mean of the aromatic C–C bonds is **1·38** for the benzyl group and **1·39** Å for the phenyl group of (1), and **1·37** Å for each benzene ring of (2). The C–H bond lengths of (2) (Table 6) are in the range **0·83**—**1·07** Å (mean **0·96** Å). These values agree with those obtained in a preceding crystallographic investigation on a related compound.[10] The piperidinium nitrogen of both derivatives has a tetrahedral con-

TABLE 3

Final positional and isotropic temperature parameters for hydrogen atoms in (2), with estimated standard deviations in parentheses

	x	y	z	B/Å^2
H(1)[O]	0·294(2)	0·108(5)	0·022(3)	5·7(1·1)
H(2)[O]	0·290(2)	0·154(4)	0·087(3)	5·5(1·0)
H(1)[C(2)]	0·179(1)	0·040(3)	0·257(2)	2·2(0·6)
H(2)[C(2)]	0·113(1)	0·089(3)	0·228(2)	1·5(0·6)
H(1)[C(3)]	0·093(1)	0·050(3)	0·098(2)	2·5(0·6)
H(2)[C(3)]	0·146(1)	0·168(3)	0·125(2)	1·7(0·6)
H(1)[C(4)]	0·028(1)	0·231(3)	0·087(2)	1·7(0·6)
H(1)[C(5)]	0·064(1)	0·463(3)	0·119(2)	1·6(0·5)
H(2)[C(5)]	0·127(2)	0·431(3)	0·141(2)	2·8(0·7)
H(1)[C(6)]	0·092(2)	0·330(3)	0·245(2)	3·0(0·7)
H(2)[C(6)]	0·147(1)	0·443(3)	0·279(2)	2·9(0·7)
H(1)[C(7)]	0·233(2)	0·142(3)	0·405(2)	3·2(0·7)
H(2)[C(7)]	0·223(2)	0·303(3)	0·414(2)	3·2(0·7)
H(1)[C(8)]	0·215(1)	0·300(3)	0·234(2)	1·8(0·6)
H(1)[C(9)]	0·272(2)	0·066(5)	0·324(3)	8·0(1·3)
H(2)[C(9)]	0·314(2)	0·168(4)	0·404(3)	4·4(0·9)
H(3)[C(9)]	0·311(2)	0·201(4)	0·334(2)	3·1(0·9)
H(1)[C(10)]	0·238(2)	0·512(4)	0·316(2)	4·8(0·8)
H(2)[C(10)]	0·285(2)	0·421(3)	0·409(2)	2·9(0·7)
H(3)[C(10)]	0·300(2)	0·448(4)	0·351(2)	3·0(0·8)
H(1)[C(12)]	0·162(1)	−0·035(3)	0·380(2)	3·1(0·7)
H(1)[C(13)]	0·084(2)	−0·112(4)	0·384(3)	5·0(0·9)
H(1)[C(14)]	0·024(2)	0·052(3)	0·386(2)	3·7(0·8)
H(1)[C(15)]	0·045(2)	0·294(4)	0·392(2)	4·0(0·8)
H(1)[C(16)]	0·125(2)	0·366(3)	0·396(2)	2·8(0·7)
H(1)[C(22)]	0·100(2)	0·373(4)	0·003(2)	3·7(0·8)
H(1)[C(23)]	0·036(2)	0·408(4)	−0·152(2)	3·7(0·8)
H(1)[C(24)]	−0·067(2)	0·328(3)	−0·262(2)	3·4(0·7)
H(1)[C(25)]	−0·119(2)	0·224(3)	−0·222(2)	3·0(0·7)
H(1)[C(26)]	−0·056(1)	0·202(3)	−0·064(2)	2·5(0·7)

TABLE 4

Bond lengths (Å) and angles (deg.) in (1)

(*a*) Distances

N(1)–C(2)	1·52(1)	C(11)–C(12)	1·39(1)
C(2)–C(3)	1·55(1)	C(12)–C(13)	1·38(1)
C(3)–C(4)	1·52(1)	C(13)–C(14)	1·40(1)
C(4)–C(5)	1·53(1)	C(14)–C(15)	1·36(1)
C(5)–C(6)	1·52(1)	C(15)–C(16)	1·35(1)
C(6)–N(1)	1·52(1)	C(16)–C(11)	1·41(1)
N(1)–C(7)	1·56(1)	C(21)–C(22)	1·39(1)
N(1)–C(8)	1·52(1)	C(22)–C(23)	1·38(1)
C(8)–C(9)	1·52(1)	C(23)–C(24)	1·38(1)
C(7)–C(11)	1·49(1)	C(24)–C(25)	1·38(1)
C(4)–C(21)	1·51(1)	C(25)–C(26)	1·39(1)
		C(26)–C(21)	1·41(1)

(*b*) Angles

C(2)–N(1)–C(8)	108·6(5)	C(7)–C(11)–C(12)	121·1(7)
C(6)–N(1)–C(7)	104·9(5)	C(7)–C(11)–C(16)	120·1(7)
C(6)–N(1)–C(8)	113·2(5)	C(12)–C(11)–C(16)	118·7(7)
C(7)–N(1)–C(8)	111·0(5)	C(11)–C(12)–C(13)	119·2(8)
C(7)–N(1)–C(2)	108·9(5)	C(12)–C(13)–C(14)	121·0(8)
C(2)–N(1)–C(6)	110·2(5)	C(13)–C(14)–C(15)	118·6(9)
N(1)–C(2)–C(3)	113·0(5)	C(14)–C(15)–C(16)	122·0(9)
C(2)–C(3)–C(4)	111·2(6)	C(15)–C(16)–C(11)	120·4(8)
C(3)–C(4)–C(5)	109·5(6)	C(4)–C(21)–C(22)	125·1(6)
C(4)–C(5)–C(6)	109·7(6)	C(4)–C(21)–C(26)	118·2(6)
C(5)–C(6)–N(1)	112·3(6)	C(22)–C(21)–C(26)	116·7(6)
C(3)–C(4)–C(21)	111·4(5)	C(21)–C(22)–C(23)	121·8(7)
C(5)–C(4)–C(21)	113·4(6)	C(22)–C(23)–C(24)	120·5(8)
N(1)–C(8)–C(9)	116·1(6)	C(23)–C(24)–C(25)	119·7(8)
N(1)–C(7)–C(11)	114·4(6)	C(24)–C(25)–C(26)	119·3(8)
		C(25)–C(26)–C(21)	121·9(7)

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[10] W. Fedeli, F. Mazza, and A. Vaciago, *J. Chem. Soc.* (*B*), 1970, 1218.

figuration with an equatorial benzyl group and an axial alkyl group. The angle between the mean plane of the piperidinium chair ring and the axial N(1)–C(8) bond is 81·3 for (1) and 83·9° for (2). The angle between the same plane and the equatorial N(1)–C(7) bond is 29·4 for (1) and 25·0° for (2). The 4-phenyl groups are in equatorial positions in both cases: the angle between the piperidinium ring mean plane and the equatorial C(4)–C(21) bond is 14·0° for (1) and 14·2° for (2). However, the conformation of the substituents on the piperidinium ring is different in the two derivatives: the dihedral angle between the mean plane of the piperidinium ring and that of the benzyl group is 49·3 for (1) and 87·4° for (2), whereas the dihedral angle between the same piperidinium ring plane and the mean plane of the 4-phenyl group is 52·0° for (1) and 79·0° for (2). Other conformational details can be deduced from the relevant torsion angles for the two derivatives (Tables 9 and 10). The piperidinium ring closely approaches a regular chair for both derivatives. The bulky phenyl and benzyl substituents do not distort the regular chair form of the piperidinium ring probably because both occupy equatorial positions.

TABLE 5

Bond lengths (Å) and angles (deg.) for non-hydrogen atoms in (2)

(*a*) Distances

N(1)–C(2)	1·516(3)	C(11)–C(12)	1·374(5)
C(2)–C(3)	1·508(5)	C(12)–C(13)	1·379(9)
C(3)–C(4)	1·533(4)	C(13)–C(14)	1·375(8)
C(4)–C(5)	1·521(4)	C(14)–C(15)	1·361(6)
C(5)–C(6)	1·512(5)	C(15)–C(16)	1·376(8)
C(6)–N(1)	1·519(4)	C(16)–C(11)	1·380(6)
N(1)–C(7)	1·532(5)	C(21)–C(22)	1·376(7)
N(1)–C(8)	1·539(6)	C(22)–C(23)	1·373(5)
C(8)–C(9)	1·516(5)	C(23)–C(24)	1·376(5)
C(8)–C(10)	1·508(5)	C(24)–C(25)	1·354(7)
C(7)–C(11)	1·509(6)	C(25)–C(26)	1·380(5)
C(4)–C(21)	1·504(4)	C(26)–C(21)	1·385(4)

(*b*) Angles

C(2)–N(1)–C(8)	110·5(3)	C(7)–C(11)–C(12)	120·1(4)
C(6)–N(1)–C(7)	109·1(3)	C(7)–C(11)–C(16)	120·7(3)
C(6)–N(1)–C(8)	111·3(3)	C(12)–C(11)–C(16)	119·2(4)
C(8)–N(1)–C(7)	109·0(2)	C(11)–C(12)–C(13)	120·4(4)
C(2)–N(1)–C(7)	109·8(2)	C(12)–C(13)–C(14)	119·6(4)
C(6)–N(1)–C(2)	107·2(2)	C(13)–C(14)–C(15)	120·3(6)
N(1)–C(2)–C(3)	113·2(2)	C(14)–C(15)–C(16)	120·1(5)
C(2)–C(3)–C(4)	110·7(3)	C(15)–C(16)–C(17)	120·3(3)
C(3)–C(4)–C(5)	107·9(2)	C(4)–C(21)–C(22)	123·0(2)
C(4)–C(5)–C(6)	110·7(3)	C(4)–C(21)–C(26)	119·6(4)
C(5)–C(6)–N(1)	112·8(4)	C(22)–C(21)–C(26)	117·4(3)
C(3)–C(4)–C(21)	112·5(3)	C(21)–C(22)–C(23)	121·3(3)
C(5)–C(4)–C(21)	114·2(3)	C(22)–C(23)–C(24)	120·0(5)
N(1)–C(8)–C(9)	112·3(3)	C(23)–C(24)–C(25)	120·0(4)
N(1)–C(8)–C(10)	112·6(4)	C(24)–C(25)–C(26)	119·7(3)
C(9)–C(8)–C(10)	110·6(3)	C(25)–C(26)–C(21)	121·7(4)
N(1)–C(7)–C(11)	116·2(2)		

TABLE 6

Bond lengths (Å) involving hydrogen atoms in (2)

O–H(1)	0·83	C(9)–H(2)	0·86
O–H(2)	0·93	C(9)–H(3)	0·85
C(2)–H(1)	1·02	C(10)–H(1)	1·02
C(2)–H(2)	0·92	C(10)–H(2)	0·90
C(3)–H(1)	1·00	C(10)–H(3)	0·93
C(3)–H(2)	1·01	C(12)–H(1)	0·89
C(4)–H(1)	1·01	C(13)–H(1)	0·93
C(5)–H(1)	0·94	C(14)–H(1)	0·96
C(5)–H(2)	0·98	C(15)–H(1)	1·00
C(6)–H(1)	1·07	C(16)–H(1)	0·98
C(6)–H(2)	0·94	C(22)–H(1)	0·98
C(7)–H(1)	0·96	C(23)–H(1)	0·86
C(7)–H(2)	0·95	C(24)–H(1)	0·93
C(8)–H(1)	1·01	C(25)–H(1)	0·97
C(9)–H(1)	1·09	C(26)–H(1)	0·86

TABLE 7

Relevant least-squares planes * for (1), and atomic displacements (Å)

Plane (1): C(11)—(16)

$$0{\cdot}6678X - 0{\cdot}7421Y + 0{\cdot}0579Z = -1{\cdot}1700$$

C(11) −0·020, C(12) 0·016, C(13) 0·006, C(14) −0·024, C(15) 0·020, C(16) 0·002

Plane (2): N(1), C(2)—(6)

$$-0{\cdot}0403X + 0{\cdot}8793Y + 0{\cdot}4746Z = 6{\cdot}9131$$

N(1) 0·211, C(2) −0·204, C(3) 0·227, C(4) −0·256, C(5) 0·264, C(6) −0·243

Dihedral angle between planes (1) and (2): 49·3°

Plane (3): C(21)—(26)

$$0{\cdot}6561X - 0{\cdot}2955Y - 0{\cdot}6944Z = -6{\cdot}5407$$

C(21) 0·021, C(22) −0·014, C(23) −0·009, C(24) 0·024, C(25) −0·016, C(26) −0·006

Dihedral angle between planes (2) and (3): 52·0°

Plane (4): C(2), C(3), C(5), C(6)

$$0{\cdot}0996X + 0{\cdot}7133Y + 0{\cdot}6938Z = 9{\cdot}3648$$

C(2) 0·022, C(3) −0·022, N(1) 0·642, C(5) 0·022, C(6) −0·022, C(4) −0·700

* The equations are in the form $AX + BY + CZ = D$ where X, Y, and Z are in Å units.

TABLE 8

Relevant least-squares planes * for (2) and atomic displacements (Å)

Plane (1): C(11)—(16)

$$0{\cdot}0338X - 0{\cdot}0176Y + 0{\cdot}7072Z = 5{\cdot}4990$$

C(11) 0·011, C(12) −0·004, C(13) −0·008, C(14) 0·012, C(15) −0·005, C(16) −0·007

Plane (2): N(1), C(2)—(6)

$$0{\cdot}9605X + 0{\cdot}2777Y - 0{\cdot}6424Z = 1{\cdot}4956$$

N −0·225, C(2) 0·235, C(3) −0·245, C(4) 0·247, C(5) −0·252, C(6) 0·240

Dihedral angle between planes (1) and (2) 87·4°

Plane (3): C(21)—(26)

$$-0{\cdot}4556X + 0{\cdot}8901Y + 0{\cdot}3183Z = 1{\cdot}9520$$

C(21) 0·001, C(22) 0·005, C(23) −0·005, C(24) −0·001, C(25) 0·006, C(26) −0·006

Dihedral angle between planes (2) and (3) 79·0°

Plane (4): C(2), C(3), C(5), C(6)

$$0{\cdot}9111X + 0{\cdot}3748Y - 0{\cdot}3748Z = 2{\cdot}2219$$

C(2) −0·003, C(3) 0·003, N(1) −0·687, C(5) −0·003, C(6 0·003, C(4) 0·710

* See footnote to Table 7.

The hydrogen bonding interaction between water molecules and chloride anions is an interesting feature of the structure of (2). A water molecule forms two hydrogen bonds. The first O–H(2) · · · Cl occurs between the oxygen and the chlorine of the same asymmetric unit, with a donor–acceptor distance of **3·32** Å, but with the chlorine and the hydrogen atoms only **2·39** Å apart, significantly nearer than the van der Waals radii sum; the associated angle O–H(2) · · · Cl is **176·8°**. The other O–H(1) · · · Cl′ interaction occurs between the same oxygen and the chlorine atom of a different asymmetric unit; the two asymmetric units are related by an inversion centre plus 1/2 translation along the *a* and *b* axes. The donor–acceptor separation of **3·23** Å is a little shorter than that for O–H(2) · · · Cl, the chlorine and the hydrogen atoms involved are only 2·42 Å apart, the associated angle O–H(1) · · · Cl′ is 169·7°. The two protons deviate from the plane of the two oxygen and the two chlorine atoms by **0·10** Å for the H(1) atom and, on the same side, **0·04** Å for the H(2) atom.

TABLE 9

Torsion angles * (deg.) in (1)

N(1)–[C(2)–C(3)]–C(4)	−53·4
C(2)–[C(3)–C(4)]–C(5)	56·2
C(3)–[C(4)–C(5)]–C(6)	−59·4
C(4)–[C(5)–C(6)]–N(1)	59·9
C(5)–[C(6)–N(1)]–C(2)	−55·4
C(6)–[N(1)–C(2)]–C(3)	51·7
C(3)–[C(4)–C(21)]–C(22)	−101·6
C(3)–[C(4)–C(21)]–C(26)	77·4
C(5)–[C(4)–C(21)]–C(22)	22·4
C(5)–[C(4)–C(21)]–C(26)	−158·5
C(2)–[N(1)–C(8)]–C(9)	171·5
C(6)–[N(1)–C(8)]–C(9)	48·8
C(2)–[N(1)–C(7)]–C(11)	59·7
C(6)–[N(1)–C(7)]–C(11)	177·6
C(8)–[N(1)–C(7)]–C(11)	−59·8
N(1)–[C(7)–C(11)]–C(12)	94·8
N(1)–[C(7)–C(11)]–C(16)	−89·1

* The sign convention is that of W. Klyne and V. Prelog, *Experientia*, 1960, **16**, 521.

TABLE 10

Torsion angles * (deg.) in (2)

N(1)–[C(2)–C(3)]–C(4)	−58·8
C(2)–[C(3)–C(4)]–C(5)	57·4
C(3)–[C(4)–C(5)]–C(6)	−57·9
C(4)–[C(5)–C(6)]–N(1)	59·8
C(5)–[C(6)–N(1)]–C(2)	−56·1
C(6)–[N(1)–C(2)]–C(3)	55·9
C(3)–[C(4)–C(21)]–C(22)	−73·5
C(3)–[C(4)–C(21)]–C(26)	106·5
C(5)–[C(4)–C(21)]–C(22)	49·9
C(5)–[C(4)–C(21)]–C(26)	−130·1
C(2)–[N(1)–C(8)]–C(9)	−60·5
C(2)–[N(1)–C(8)]–C(10)	173·8
C(6)–[N(1)–C(8)]–C(9)	−179·5
C(6)–[N(7)–C(8)]–C(10)	54·8
C(2)–[N(7)–C(7)]–C(11)	−56·8
C(6)–[N(7)–C(7)]–C(11)	60·4
N(1)–[C(7)–C(11)]–C(12)	93·5
N(1)–[C(7)–C(11)]–C(16)	−89·7

* See footnote to Table 9.

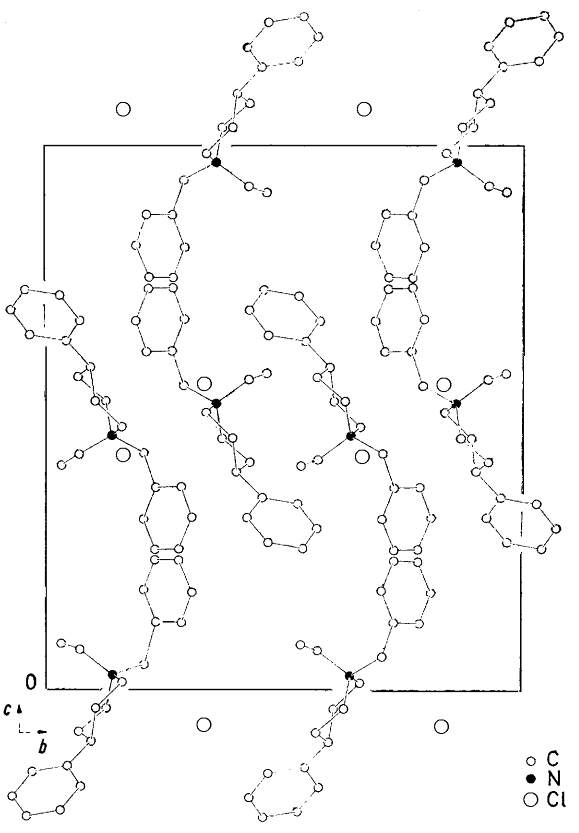

FIGURE 3 The unit-cell content of the crystal of (1) projected down the *a* axis

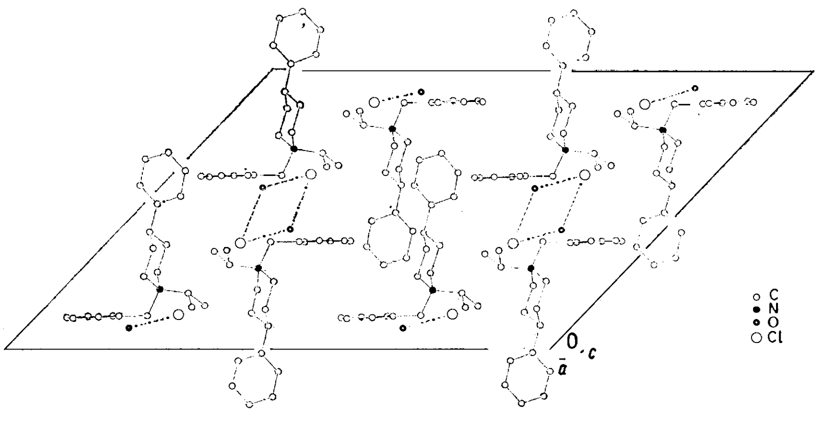

FIGURE 4 Unit-cell content of the crystal of (2) projected down the *b* axis. Dashed lines connecting oxygen and chlorine atoms represent hydrogen bonds

This hydrogen-bonding interaction as well as the electrostatic interaction between the chloride and the positively charged piperidinium ions, seem to play an essential role in determining the final crystal packing (Figures 3 and 4).

Chemical Conclusions.—The crystal structure analysis of the two major isomers obtained from reaction of 1-ethyl-4-phenylpiperidine and 1-isopropyl-4-phenylpiperidine with benzyl chloride in acetonitrile solution reveals that the quaternizing agent has taken up the equatorial position whilst both the ethyl and the larger isopropyl group are constrained to the axial position. As discussed in the preceding paper,[2] we conclude that *N*-benzylation of piperidines normally occurs by preferential equatorial attack.

We thank Professor A. R. Katritzky for supplying crystals of the major quaternization products, and N. Ocello for technical assistance. One of us (J. R. C.) acknowledges a fellowship under the Royal Society–Accademia Nazionale dei Lincei European Programme.

[3/278 *Received, 6th February,* 1973]