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PROTON MAGNETIC RESONANCE STUDIES OF CYCLIC COMPOUNDS—II†

N- AND 2-SUBSTITUTED CYCLOHEXYLAMINES

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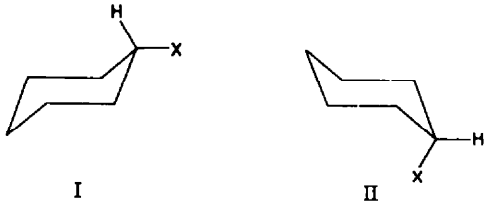
Abstract—PMR spectra are recorded for a number of N- and 2-substituted cyclohexylamines, and are discussed in terms of stereochemical and conformational features. The *cis*- or *trans*- geometry of a 2-alkyl-cyclohexylamine is readily assessed from the PMR spectrum of the amine or the phthaloyl derivative. Analysis of the α-proton signal of *cis*-2-alkylcyclohexylamines gives only crude information about the conformational equilibrium.

STUDIES of the decomposition of quaternary hydroxides required the synthesis of a number of *cis*- and *trans*-2-alkylcyclohexylamines. Whilst a few stereospecific synthesis of these amines are available, it seemed likely that the PMR spectra of the amines, or of simple derivatives, would allow a rapid diagnosis of stereochemical features. In addition, it was possible that the spectra would allow conclusions to be drawn as to the position of conformation equilibrium in systems showing mobility.

In general, two features of the PMR spectra of mono- and disubstituted cyclohexanes are of interest: (i) the position and shape of signals at low field, due to ring protons on the carbon atom α to the substituents; (ii) the position and shape of the resonance due to the remaining ring protons. For alkyl substituents, the α-proton



I II

signal is not usually seen, being swamped by the signals due to the remaining ring protons. However, many substituents, e.g. hydroxyl, amino, nitro, halogen, exert a deshielding effect large enough to pull the α-proton resonance to low field of the resonance envelope due to the remaining ring protons. A monosubstituted cyclohexane $C_6H_{11}X$ usually undergoes ring inversion between conformation (I), in which the α-proton is axial, and conformation (II), in which the α-proton is equatorial. There is normally an appreciable difference, 0·3 to 0·8 ppm, in chemical shift between axial and equatorial protons in otherwise identical environments; the equatorial proton is almost invariably at lower field. At room temperature, however, the rate of ring

† Part I, H. Booth, *J. Chem. Soc.* 1841 (1964).

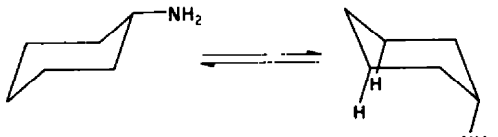
inversion is much greater than the frequency difference between the signals for equatorial and axial protons. Thus a single resonance, representing an averaged chemical shift, is observed.

Valuable information about the equilibrium (I) $\rightleftharpoons$ (II) of mobile systems has been gained from PMR studies, two different techniques having been employed. In the first method, the spectrum is recorded at low temperatures.[1] If a sufficiently low temperature can be reached without experimental troubles becoming insuperable, the equilibrium is 'frozen' and the α-proton resonance will consist of two signals, one characteristic of the equatorial proton in II and one characteristic of the axial proton in I. The relative areas of the two signals give the proportions of the two conformations. In a second method,[2,3] the position of the α-proton signal in the spectrum of cyclohexyl-X is compared with that in the spectra of *cis*- and *trans*-4-t-butylcyclohexyl-X, two molecules which are expected to be conformationally homogeneous, with the α-proton equatorial and axial respectively. Both methods have been used to calculate, for a given substituent, the conformational free energy difference (ΔG, or A-value) between I and II. A third method, in which the α-proton signal is analysed in terms of averaged coupling constants, has been described,[4] but this method already needs to be modified in view of (a) appreciable coupling between equatorial protons in 1,3-positions,[5] and (b) the likelihood that $J_{ae} \neq J_{ea}$ in some cases.[6] Two further methods are discussed by Feltkamp and Franklin.[7]

We have concentrated on examination of the shape and splitting of the α-proton signals, but the signals due to other ring protons are of interest and these will be discussed first. The spectrum[8–10] of cyclohexane at room temperature shows a single resonance at $\tau = 8{\cdot}5$. Here axial and equatorial protons have the same chemical shift because rapid inversion of *equivalent* chair conformations converts an equatorial proton into an axial proton and *vice-versa*. When the interconversion is prevented by working at $-90°$, the spectrum shows two multiplets, one at $\tau = 8{\cdot}35$ due to equatorial protons and one at $\tau = 8{\cdot}83$ due to axial protons. These results have led to a widespread belief that a narrow resonance for ring protons inevitably implies rapid ring-inversion. Now when the cyclohexane ring is substituted by a group with a large deshielding effect on β-protons, the β- and γ-protons will then have different chemical shifts and a sharp line is not expected for ring protons, whether or not rapid inversion is occurring. For an amino group, the deshielding effect on the β-protons of *acyclic* compounds is small, so that rapid inversion of chair conformations might cause the β, γ and δ-protons to become equivalent. However, the rigid geometry of the cyclic system will probably cause the β-protons to be subjected to differential shielding or deshielding effects, depending on whether they are axial or equatorial, and also

[1] W. C. Neikam and B. P. Dailey, *J. Chem. Phys.* **38**, 445 (1963).
[2] E. L. Eliel, *J. Chem. Education* **37**, 126 (1960).
[3] E. L. Eliel and M. H. Gianni, *Tetrahedron Letters* 97 (1962).
[4] H. Booth, *Tetrahedron* **20**, 2211 (1964).
[5] A. Rassat, C. W. Jefford, J. M. Lehn and B. Waegell, *Tetrahedron Letters* 233 (1964).
[6] N. S. Bhacca and D. H. Williams, *J. Amer. Chem. Soc.* **86**, 2742 (1964).
[7] H. Feltkamp and N. C. Franklin, *Liebigs Ann* in press.
[8] W. B. Moniz and J. A. Dixon, *J. Amer. Chem. Soc.* **83**, 1671 (1961).
[9] F. R. Jensen, D. S. Noyce, C. H. Sederholm and A. J. Berlin, *J. Amer. Chem. Soc.* **82**, 1256 (1960); **84**, 386 (1962).
[10] N. Muller and W. C. Tosch, *J. Chem. Phys.* **37**, 1167 (1962).

whether the amino group is axial or equatorial. Clear evidence for such effects has already been collected in the case of the methyl group[11] and also for a variety of other groups,[12] excluding the amino group. Furthermore, it is also unlikely that the γ-protons will be equivalent to the δ-protons, since the shielding of the axial γ-protons in (IV) is likely to be influenced by the proximity of the axial NH_2 group (cf.[12]), an effect not possible for the δ-protons.



III IV

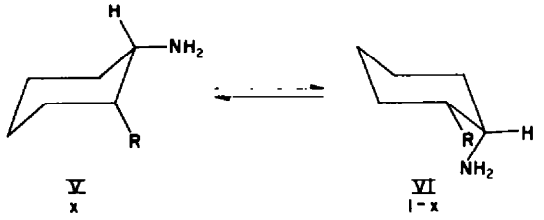
Thus the ring protons of III and IV are unlikely to be magnetically equivalent. Such considerations make it most unlikely that monosubstituted cyclohexanes undergoing rapid interconversion of conformations will show a sharp signal for ring protons. Published spectra support this; for example, a broad resonance for ring protons is observed for methylcyclohexane, cyclohexanol and bromocyclohexane. It is also doubtful whether the observation of a sharp resonance is *necessarily* an indication of rapid interchange of conformations. Thus, *cis*-1-methyl-4-t-butylcyclohexane shows a narrow resonance[10] for ring protons, in spite of the fact that the molecule is almost certainly a rigid chair. Our results for cyclohexylamines may be summarized thus: *cis*-2-alkylcyclohexylamines show a narrow resonance for ring protons;[13] all others, such as *trans*-2-alkylcyclohexylamines, N-substituted *cis*-2-alkylcyclohexylamines, N-substituted *trans*-2-alkylcyclohexylamines, and cyclohexylamine itself show a broad resonance for ring protons. The sharpness of the ring proton signal in *cis*-2-alkylcyclohexylamines is quite marked and can be used to distinguish such molecules from their *trans*-isomers. In the case of 2-methylcyclohexylamine, the ring proton resonance of the *cis*-amine has a half-band width of only 11 c/s, whilst the corresponding resonance in the *trans*-amine includes many peaks and is spread over about 50 c/s.

As mentioned above, we have concentrated largely on examination of the α-proton signal of cyclohexylamines and acyl derivatives. Chemical Shifts are listed in Table 1. In the case of the free amines, the α-proton signal was not usually resolved, and was unaffected by deuteration of the proton(s) attached to nitrogen. Thus, spin–spin coupling between the α-proton and the protons of the NH or NH_2 group was undetectable, probably because of very rapid exchange of protons between amine and amine,[14] and/or amine and water, a state of affairs which was also inferred from the sharpness of the NH resonance and from the variation of the NH chemical shift with concentration.

For *cis*-2-alkylcyclohexylamines, the α-proton signals were at much lower field than those due to other ring protons, and the lack of fine structure is probably due to the similarity in magnitude of J_{ae} and J_{ee}, as well as to broadening due to small long-range

[11] E. L. Eliel, M. H. Gianni, T. H. Williams and J. B. Stothers, *Tetrahedron Letters* 741 (1962).
[12] N. S. Bhacca and D. H. Williams, *Application of* NMR *Spectroscopy in Organic Chemistry* p. 185. Holden-Day, San Francisco (1964).
[13] Cf. S. Brownstein and R. Miller, *J. Org. Chem.* 24, 1886 (1959).
[14] Cf. J. Feeney and L. H. Sutcliffe, *J. Chem. Soc.* 1123 (1962).

couplings.[5] When the α-proton signal is at relatively high field, as in *trans*-2-alkylcyclohexylamines, an additional factor causing ill-resolved signals is the fact that first order conditions do not hold accurately, as the difference in chemical shift between the α-protons and the β-protons is not large compared with the coupling constants involved. A general method of analysis of α-proton signals in mobile cyclohexane systems has been described.[4] It was estimated that cyclohexylamine in benzene exists to the extent of 80% in the conformation with NH_2 equatorial. A *cis*-2-alkylcyclohexylamine is expected to consist of a mixture of rapidly interconverting conformations V and VI.



V x VI 1 - x

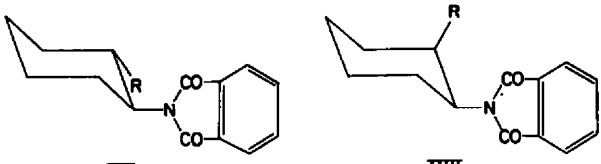
By application of the general method,[4] and assuming first order conditions, the α-proton signal is expected to be a doublet [separation $J^* = xJ_{aa} + (1 - x)J_{ee}$], each component being a triplet (separations J_{ae}). Taking J_{aa} as 10·6 c/s, J_{ae} as 3·2 c/s and J_{ee} as 2·2 c/s, the appearance of the α-proton signal can be calculated for various values of x. For all the *cis*-2-alkylcyclohexylamines examined, the α-proton signal was clearly observed at low field as a fairly narrow, unresolved peak of half-band width 6–8 c/s. It was concluded that all these amines existed in benzene to an extent >75% in conformation (VI), with NH_2 axial. As some of the amines, e.g.*cis*-2- cyclohexylcyclohexylamine, gave an α-proton signal with a band width *less* than that calculated for a conformationally homogeneous system with NH_2 axial, it seems that, for reasons at present unknown, the band width method is inaccurate for 2-alkylcyclohexylamines. An analogous discrepancy occurs with *cis*-2-isopropylcyclohexanol, so that, the anomaly is probably general for 1,2-disubstituted cyclohexanes. However, it is clear from the figures that, in benzene at least, NH_2 is less space-demanding than methyl[15] (for results in other solvents, Ref. 16).

trans-2-Alkylcyclohexylamines are expected to exist almost entirely in the conformation with both substituents equatorial i.e. with the α-proton axial. Unfortunately, in the PMR spectra of the amines, the α-proton resonance was not clearly seen, but was continuous with the resonance of the ring protons. Although this fact in itself was a useful means of differentiating *cis*- and *trans*-2-alkylcyclohexylamines it was desirable to find a derivative of which the PMR spectrum would give immediate positive evidence of the configuration of the amine. The acetyl, benzoyl and benzenesulphonyl derivatives of cyclohexylamine were examined, since they were expected to be conformationally homogeneous. However, despite the fact that the deshielding influence of the acyl group caused the α-proton resonance to be clearly seen at low field, the actual signal showed no fine structure, even in the N-deuterated specimens. Fortunately, the N-phthaloyl derivative (VII; R = H) of cyclohexylamine gave an

[15] Cf. H. Booth and N. C. Franklin, *Chem. & Ind.* 954 (1963).

[16] E. L. Eliel, E. W. Della and T. H. Williams, *Tetrahedron Letters* 831 (1963); J. Sicher, J. Jones and M. Tichy, *Ibid.* 825 (1963).

α-proton signal, at $\tau = 5{\cdot}82$, which was fully resolved; it appeared as a triplet (separations 11·4 c/s = J_{aa}), each component being a triplet (separations 3·8 c/s = J_{ae}). Similar signals were given also by succinimido- and maleimidocyclohexane. The N-phthaloyl derivatives of *trans*-2-alkylcyclohexylamines also gave sharply resolved α-proton signals, with separations in agreement with conformation (VII). Thus



VII VIII

the α-proton signal of *trans*-2-ethyl-1-phthalimidocyclohexane was a triplet (J_{aa} = 11·6 c/s), each component a doublet (J_{ae} = 3·9 c/s). Our first attempts to prepare the phthaloyl derivative of *cis*-2-methylcyclohexylamine failed.[15] This failure seemed reasonable at first, since Macbeth *et al.*[17] had reported the impossibility of preparing the phthaloyl derivative of neomenthylamine by cyclization of the corresponding phthalamic acid. Later we were successful in preparing the phthaloyl derivatives of *cis*-2-alkylcyclohexylamines by a one-stage method which we regard as the preferred method, namely, the treatment of the amine with phthalic anhydride in boiling acetic acid for 5–8 hr. The N-phthaloyl derivatives of the *cis*-2-alkylcyclohexylamines gave sharply-resolved α-proton signals in agreement with conformation VIII. For example, *cis*-2-ethyl-1-phthalimidocyclohexane (VIII; R = Et) gave, at $\tau = 5{\cdot}60$, a doublet (J_{aa} = 12·3 c/s), each component of which was a triplet (J_{ae} = 3·0 c/s). Data for chemical shifts and coupling constants of all the phthalimido-derivatives prepared are given in Table 2. It is noticeable that J_{aa} for imides from *trans*-2-alkylcyclohexylamines is consistently smaller than J_{aa} for imides from the corresponding *cis*-amines.

A number of generalizations can be made from the data in Tables 1 and 2:

(1) the effect on an axial hydrogen, of replacing the equatorial hydrogen on an adjacent carbon atom by an n-alkyl group is one of *shielding*. The magnitude of the effect is in the order Me ≫ Et, Pr, Bu;

(2) the effect on an equatorial hydrogen, of replacing the equatorial hydrogen on an adjacent carbon atom by an n-alkyl group is one of *shielding*. The magnitude of the effect is in the order Me ≫ Et, Pr, Bu;

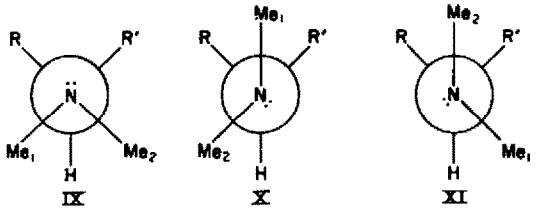
(3) the effect on an axial hydrogen, of replacing the axial hydrogen on an adjacent carbon atom by an n-alkyl group is one of *deshielding*. The magnitude of the effect is similar for Me, Et, Pr and Bu.

These conclusions are similar to those obtained by Eliel *et al.*[11] from the spectra of 2-alkylcyclohexanols.

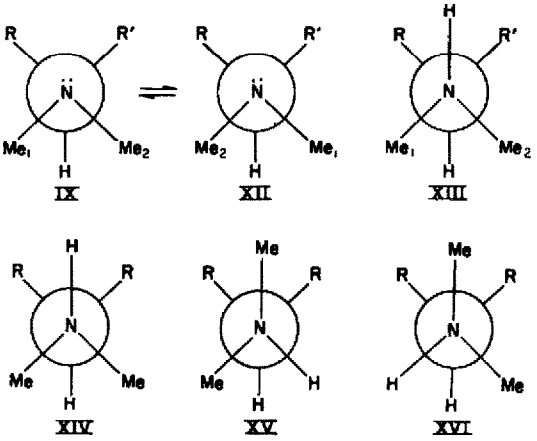
During the work on N-substituted phthalimides, methods of cyclising phthalamic acids to phthalimides were briefly investigated. Equally good yields were obtained by heat (just above m.p.), boiling acetic anhydride or boiling acetyl chloride, although the last reagent gave the purest product. For the cyclisation of succinamic acids, boiling acetic anhydride appeared to be the best reagent.

[17] A. K. Macbeth, J. A. Mills and W. G. P. Robertson, *J. Chem. Soc.* 2968 (1951).

Table 1 includes details of the NMR spectra of the N,N-dimethyl derivatives of *cis*- and *trans*-2-alkylcyclohexylamines. Di-N-methylation of cyclohexylamines leads to a pronounced shielding of the α-proton. The effect appears to be general, as, for example, the chemical shifts of the 2,6-protons in 1-methylpiperidine and of the 3,5-protons in 4-methylmorpholine, are about 0·3 to 0·4 ppm to high field of the corresponding protons in piperidine and morpholine respectively. As regards cyclohexylamines, the result of this effect is that the signal for the α-proton is now lost beneath the general absorption due to ring protons. The N-methyl protons appear as sharp singlets in the spectra of the N,N-dimethyl-2-alkylcyclohexylamines.



Now conformations IX, X and XI are the most stable conformations of the tertiary amines, with respect to rotation about the ring carbon–N bond. If free rotation is assumed, conformations IX to XI will be equally populated. However, each methyl group is not subject to the same average shielding (e.g. shielding of Me_1 in IX $\neq$ shielding of Me_2 in X), so that a singlet is not expected for the N-methyl protons. The observation of a singlet is evidently a consequence of the rapid inversion of nitrogen (e.g. IX $\rightleftharpoons$ XII), which gives each methyl group the same average shielding.



If this explanation is correct, the situation should be altered by protonation of the nitrogen, which prevents the inversion. In agreement, *two* signals (each a doublet, J ~ 5 c/s, due to coupling with the proton on nitrogen) were obtained for the N-methyl protons of protonated N,N-dimethyl-2-alkylcyclohexylamines (XIII), due to the non-equivalence of the N-methyl groups.

The difference in chemical shift between the N-methyl groups of protonated 2-alkyl-N,N-dimethylcyclohexylamines is greater for the *trans*- than the *cis*-compounds.

TABLE 1. CHEMICAL SHIFT DATA (τ VALUES) FOR N- AND 2-SUBSTITUTED CYCLOHEXYLAMINES (SPLITTINGS J IN c/s)

Derivative	Solv.	N-H	N-Me	α-proton	α-proton ½-band width (c/s)	Misc.
Unsubstituted	1	9·1	—	7·52[a] (J 10)	20	—
Unsubstituted	2	3·0[b]	—	6·55[b]	22	—
N-Ac	3	3·5[b]	—	6·25[b]	21	Ac 8·01
N-Bz	3	3·55[b]	—	6·00[b]	20	—
N-Benzenesulphonyl	1	3·89[c] (J 7·3)	—	6·37[b]	23	—
N-Me	1	8·9	7·72	*d*	—	—
N-Me	4	1·2[b]	7·67[e] (J 5·4)	*d*	—	—
$N\text{-}Me_2$	1	—	7·80	*d*	—	—
$N\text{-}Me_2$	4	*d*	7·72[c] (J 5·1)	*d*	—	—
NMe_2, MeI	3	—	6·56	*d*	—	—
cis-2-Me	5	—	—	7·31	8	Me 9·24[c] (J 5·7)
cis-2-Me, N-Bz	3	3·6[b,h]	—	5·67[b]	—	Me 9·06[c] (J 6·9)
trans-2-Me	1	8·7	—	8·0[f]	—	Me 9·08[c] (J 1·8)
trans-2-Me	4	2·3[b]	—	7·39[b]	20	Me 8·99[c] (J 5·5)
trans-2-Me, N-Bz	3	3·6[c] (J 9·5)	—	6·31[b]	—	Me 9·01[c] (J 4·7)
cis-2-Et[i]	1	9·4	—	7·06	7·5	—
cis-2-Et, $N\text{-}Me_2$	1	—	7·84	*d*	—	—
cis-2-Et, $N\text{-}Me_2$	4	*d*	7·76[c] (J 4·5) 7·79[c] (J 4·7)	*d*	—	—
cis-2-Et, NMe_2, MeI	3	—	6·52	*d*	—	—
trans-2-Et	1	9·06	—	7·84[f]	—	Me 9·0[g]
trans-2-Et, $N\text{-}Me_2$	1	—	7·82	*d*	—	Me 9·0[g]
trans-2-Et, $N\text{-}Me_2$	4	*d*	7·54[c] (J 4·2) 7·72[c] (J 5·1)	*d*	—	—
cis-2-Allyl, $N\text{-}Me_2$	1	—	7·74	7·4[f]	—	olefinic 4·3[g], 4·9[g]
cis-2-Allyl, $N\text{-}Me_2$	4	—	7·71[c] (J 4·4) 7·87[c] (J 5·5)	*h*	—	olefinic[h]
trans-2-Allyl, N-Bz	3	3·48[c] (J 8·8)	—	6·2[b]	27	olefinic 4·3[g], 5·0[g]
trans-2-Allyl, $N\text{-}Me_2$	1	—	7·82	*d*	—	olefinic 4·1[g], 5·0[g]
trans-2-Allyl, $N\text{-}Me_2$, MeI	3	—	6·57	*d*	—	olefinic 4·3[g], 4·9[g]
cis-2-Pr	1	8·95	—	7·09	6·5	Me 9·09[g]
cis-2-Pr, $N\text{-}Me_2$	1	—	7·85	*d*	—	Me 8·99[g]
cis-2-Pr, $N\text{-}Me_2$	4	—	7·65[c] (J 5·0) 7·69[c] (J 5·4)	*d*	—	—
trans-2-Pr, $N\text{-}Me_2$	1	—	7·87	*d*	—	—
trans-2-Pr, $N\text{-}Me_2$	4	—	7·67[c] (J 5·1) 7·86[c] (J 5·0)	*d*	—	—
cis-2-Bu[i]	1	9·4	—	7·08	7·5	Me 9·03[g]
cis-2-Bu, N-Ac	3	4·0[b]	—	5·84	9[f]	Ac 8·03, Me 9·1[g]
cis-2-Bu, $N\text{-}Me_2$[i]	1	—	7·85	*d*	—	Me 9·05[g]
cis-2-Bu, $N\text{-}Me_2$	4	—	7·66[c] (J 4·4) 7·71[c] (J 4·8)	*d*	—	Me 9·07[g]
cis-2-Bu, $N\text{-}Me_2$, MeI	3	—	6·53	*d*	—	Me 9·07[g]

TABLE 1 (*Cont'd*)

Derivative	Solv.	N-H	N-Me	α-proton	α-proton ½-band width (c/s)	Misc.
trans-2-Bu	1	9·2	—	7·9[f]	—	Me 9·07[g]
trans-2-Bu, N-Ac	3	1·67[b]	—	6·4[b]	16–20[f]	Ac 7·78, Me 9·13[g]
trans-2-Bu, N-Me_2	1	—	7·81	*d*	—	Me 8·97[g]
trans-2-Bu, N-Me_2	4	—	7·70[c] (J 5·0) 7·89[c] (J 5·1)	—	—	Me 9·1[g]
trans-2-Bu, N-Me_2, MeI	3	—	6·60	—	—	Me 9·08[g]
cis-2-cyclohexyl[i]	5	—	—	6·83	6·1	—
cis-2-cyclohexyl, N-Me_2	1	—	7·79	*d*	—	—
trans-2-cyclohexyl[k]	5	—	—	7·7[f]	—	—
trans-2-cyclohexyl, N-Me_2	1	—	7·83	*d*	—	—
trans-2-cyclohexyl, N-Me_2	4	—	7·66[c] (J 5·0) 7·82[c] (J 5·0)	*d*	—	—
trans-2-cyclohexyl, N-Me_2, MeI	3	—	6·56	—	—	—
cis-4-t-butyl	1	9·24	—	6·89	7·3	Bu[t] 9·13
trans-4-t-butyl	1	9·12	—	7·56	—	Bu[t] 9·15

Solvents: 1, benzene; 2, trifluoroacetic acid; 3, chloroform; 4, benzene and trifluoroacetic acid; 5, benzene + D_2O.

[a] Centre of poorly resolved triplet; [b] Broad; [c] Centre of doublet; [d] Not seen; [e] Centre of 1:2:1-triplet; [f] Tentative assignment (shoulder); [g] Centre of multiplet; [h] Not seen clearly; [i] Contains some *trans*-amine; [j] After treatment with NaOD; [k] Contains some *cis*-amine.

TABLE 2. SPECTRAL DATA FOR PHTHALOYL DERIVATIVES OF CYCLOHEXYLAMINE AND 2-ALKYLCYCLOHEXYLAMINES (J IN c/s)

Derivative	Solv.	α-Proton (τ)	Observed splittings J_{aa}	Observed splittings J_{ae}	Misc. (τ)
Unsubstituted	1	5·82	11·4	3·8	—
cis-2-Me	1	5·68	12·8	4·0	Me 8·95[a] (J 7·5)
trans-2-Me	2	6·22	11·3	3·8	Me 9·17[a] (J 7·1)
cis-2-Et	2	5·60	12·3	3·0	Me 9·1[b]
trans-2-Et	2	5·97	11·6	3·9	Me 9·2[b]
trans-2-allyl	1	6·07	11·0	3·4	Olefinic 4·34,[g] 5·16[g]
cis-2-Pr	1	5·61	12·0	3·7	Me 9·1[b]
trans-2-Pr	2	5·95	11·4	3·4	Me 9·3[b]
cis-2-Bu[c]	2	5·61	12·0	3·4	—
trans-2-Bu	2	5·96	11·0	3·7	Me 9·3[b]
trans-2-Cyclohexyl	1	5·82	11·5	3·9	—
trans-2-Cyclohexyl	2	5·79	11·2	3·7	—
trans-4-t-Butyl	1	5·88	11·4	3·9	Bu[t] 9·1
trans-4-t-Butyl	2	5·78	11·1	3·5	Bu[t] 9·2

Solvents: 1, chloroform; 2, benzene.

[a] Centre of doublet; [b] Centre of multiplet; [c] Contains some *trans*-imide.

This feature is useful in assigning configuration, and also in detection of mixtures of isomers, particularly when the N-methyl protons of the free bases have the same chemical shift. In all cases examined, the doublets due to the N-methyl groups of protonated *cis*-2-alkyl-N,N-dimethylcyclohexylamines show overlap, whereas the doublets in the spectra of the corresponding *trans*-compounds are well separated. In one case, that of protonated *cis*-2-cyclohexyl-N,N-dimethylcyclohexylamine, the N-methyl groups appear to be accidently equivalent, as only one doublet is seen in the spectrum. The equivalence of the N-methyl groups in protonated N,N-dimethylcyclohexylamine is expected. The shieldings of the methyl groups are identical in conformation XIV. The shieldings of the methyl groups in XV are unequal, and the same applies to conformation XVI. However, since XV and XVI are enantiomorphs, it is reasonable to expect that they are equally populated. Therefore the average shieldings of the methyl groups over conformations XIV, XV and XVI will be the same.

EXPERIMENTAL

PMR spectra were obtained on an A.E.I. Spectrometer R.S.II, operating at 60 Mc/s, with tetramethylsilane as internal reference. The preparation of the compounds will be described in a future publication.

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