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THE CONDENSED POLYNUCLEAR PERHYDRO-COMPOUNDS CONTAINING NITROGEN—XIV*

THE CONFORMATIONS OF 5,6,6a,7,8,9,10,10a-OCTAHYDROPHENANTHRIDINES

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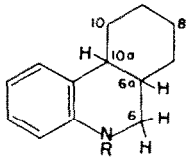
Abstract—NMR spectra are recorded for both stereoisomeric 5,6,6a,7,8,9,10,10a-octahydrophenanthridines and their derivatives, and are discussed in terms of the probable conformations adopted by the reduced heterocyclic ring.

SEVERAL years ago one of the authors (T. M.) reported, on the basis of the UV spectroscopic measurements, that *cis*-1,2,3,4,4a,9,9a,10-octahydroacridine would be fixed in one of the two possible interconvertible conformations.[1] Later, one of us (H. B.) confirmed the assignment by examination of NMR spectra, which also indicated that introduction of various substituents on the N-atom affected features of the probable conformations of the *cis* compounds.[2] On the other hand, NMR spectra of a number of 1,2,3,4-tetrahydroquinolines were measured, and the preferred conformations were determined for both those and the derived quaternary salts, especially, in order to search for the relation between thermal decomposition and conformation of the hydroxides.[3,4] However, no spectra of stereoisomeric 3,4-disubstituted tetrahydroquinolines appear to have been reported. Recently we have prepared the *cis* and *trans* isomers of



I

* Part XIII, T. Masamune, M. Ohno, M. Koshi, S. Ohuchi and T. Iwadare, *J. Org. Chem.* **29**, 1419 (1964).

[1] T. Masamune, *J. Amer. Chem. Soc.* **79**, 4418 (1957).

[2] H. Booth, *Tetrahedron* **19**, 91 (1963).

[3] H. Booth, *J. Chem. Soc.* 1841 (1964).

[4] [a] D. A. Archer, H. Booth, P. C. Crisp and J. Parrick, *J. Chem. Soc.* 333 (1963); [b] D. A. Archer, H. Booth and P. C. Crisp, *Ibid.* 249 (1964).

5,6,6a,7,8,9,10,10a-octahydrophenanthridine (I).[5] While the UV spectra suggested that the hydrogen atom at position 6a would exist in the axial conformation with respect to the reduced nitrogen ring (ring B) in both the *cis* and *trans* secondary amines, it became desirable to determine conformations of both the amines and the various N-substituted derivatives by a more efficient tool. The present paper describes the results obtained by examination of NMR spectra of the octahydrophenanthridines.

EXPERIMENTAL

Materials. Most of the *cis*- and *trans*-5,6,6a,7,8,9,10,10a-octahydrophenanthridines and the N-substituted derivatives were prepared as described earlier,[5] and the *trans* isomers were also obtained[6,7] by reduction of 7,8,9,10-tetrahydrophenanthridine[8] with sodium in boiling EtOH or with tin and HCl in EtOH. Solid compounds were newly recrystallized and liquids were freshly distilled before use. Among the compounds examined, only the N-acetyl and N-benzoyl derivatives of *cis*-octahydrophenanthridine, prepared by Takasugi, were new.

Acetylation of the *cis* secondary amine with acetic anhydride and pyridine on a steam-bath for 1 hr yielded quantitatively the N-*acetyl derivative*, b.p. 115–120° (bath temp, 4 mm), ν_{max}^{film} 1660 cm^{-1}. (Found: C, 78·34; H, 8·44. $C_{15}H_{19}NO$ requires: 78·56; H, 8·35%.)

Treatment of the *cis* secondary amine in ether with benzoyl chloride and 6N NaOH at room temp for 20 hr gave the crude N-*benzoyl derivative*, which was purified by distillation. It had b.p. 195–200° (bath temp, 4 mm), and $\nu_{max}^{CHCl_3}$ 1630 cm^{-1}. (Found: C, 82·25; H, 7·40. $C_{20}H_{21}NO$ requires: C, 82·44; H, 7·26%.)

Measurements of the spectra. The NMR spectra were obtained on a Perkin–Elmer R-10 spectrometer (abbr. P.E.), or a JEOL 3H-60 spectrometer (JEOL), or a Varian A-60 spectrometer (Va.), operating at 60 Mc. Tetramethylsilane was used as internal reference, and CH_2Cl_2, CCl_4, benzene or $CDCl_3$ as solvent. In most cases, 50–70 mg of sample were dissolved in about 0·5 ml of solvent, but in a few cases, saturated solutions (ca. 20 mg of material in 0·5 ml $CHCl_3$) were employed because of the insolubility of the compounds.

RESULTS AND DISCUSSIONS

There are two protons at position 6 of the octahydrophenanthridine (I). As these protons are located on the carbon adjacent to the N-atom, the resonance for the protons appears at lower field than that for the remaining saturated ring (ring C) protons and is readily discernible. The protons are coupled only to the proton at position 6a (proton 6a), and may therefore be expected, in a rigid conformation, to give rise to a system of eight lines similar to that given by the AB part of an ABX system. If the molecule exists as an equal mixture of rapidly interconverting conformers, the protons 6 may give a signal corresponding to the A_2 part of an A_2X system. The region involving peaks due to the protons was expanded five or six times, and the signal was analyzed by the method of Bernstein *et al.*[9] A few representative spectra will be shown in Figs. and the results are summarized in the Table with those obtained from other protons.

The secondary amines and the N-*methyl derivatives*

The spectra of *octahydrophenanthridines* (I, R = H) showed octets due to the AB part of an ABX system, at τ 6·7 to 7·3 for the *trans* isomer, m.p. 72°, and at τ 6·4 to 7·1 for the *cis* isomer, m.p. 42° (Figs. 1 and 2). While eight lines were observed in the

[5] T. Masamune, M. Takasugi, H. Suginome and M. Yokoyama, *J. Org. Chem.* **29**, 681 (1964).
[6] H. Booth, P. C. Crisp and N. C. Franklin, unpublished work.
[7] T. Masamune, Y. Kubota, G. Homma and M. Ohno, *J. Chem. Soc. Japan* **77**, 1467 (1956).
[8] B. L. Hollingsworth and L. Petrow, *J. Chem. Soc.* 1537 (1948).
[9] H. J. Bernstein, J. A. Pople and W. G. Schneider, *Canad. J. Chem.* **35**, 65 (1957).

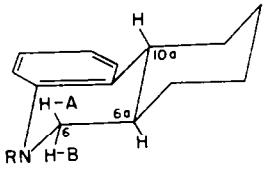
TABLE 1. THE CHEMICAL SHIFTS (τ) AND COUPLING CONSTANTS (c/s) FOR THE PROTONS OF 5,6,6α,7,8,9,10,10α-OCTAHYDROPHENANTHRIDINES

Compounds R in (1) and configuration		Solvent	Ring B protons: H-6 (H-A and H-B) τ_A	J_{AX}	τ_B	J_{BX}	J_{AB}	Ring C protons: H-10a	H-6α	others	Aromatic protons[r]	Miscellaneous[r]	Apparatus[s]
H	*cis*	CH_2Cl_2	6·66	(9·1)	6·95	(3·6)[a]	(11·0)	7·1–7·4[t]	7·8–8·2	8·2–8·7[o]	3·0–3·8	NH, 6·35 (s)	P.E. (×6)
		CCl_4	6·74	(8·9)	6·98	(3·6)[a]	(11·1)	7·1–7·4[t]	7·7–8·2	8·2–8·7[o]	3·0–3·8	NH, 6·52 (s)	Va. (×5)
		C_6H_6	6·97	(8·9)	7·24	(3·5)[a]	(11·1)[b]	7·3–7·6	7·8–8·2	8·3–8·7[o]	—	—	Va. (×5)
	trans	CH_2Cl_2	7·06	(10·1)	6·86	(3·5)	(10·8)	7·7–7·9[m]		8·0–9·1[p]	2·9–3·8	NH, 6·31 (s)	P.E. (×6)
		CCl_4	6·99	(10·4)[c]	6·80	(3·3)	(11·0)	7·6–8·1[m]		8·1–9·2[p]	2·9–3·8	NH, 6·33 (s)	JEOL (×1)
CH_3	*cis*	CCl_4	6·70	(9·5)	6·99	(4·0)[a]	(11·0)[d]	7·1–7·4[b]	7·6–8·2[f]	8·2–8·8[o]	2·9–3·8	NCH_3, 7·15 (s)	Va. (×5)
	trans	CCl_4			[e]			7·5–7·8	7·8–9·2[p,q]		2·9–3·8	NCH_3, 7·16 (s)	Va. (×5)
COC_6H_5	*cis*	$CDCl_3$	6·17	(7·7)	6·03	(6·8)	(12·3)	6·9–7·3[k]	7·4–8·0	8·0–8·7[o]	2·5–3·5	—	JEOL (×5)
	trans	$CDCl_3$	6·31	(8·2)	6·17	(6·7)	(12·2)	7·4–7·8[n]	7·8–9·0	[p,o]	2·6–3·6	—	JEOL (×5)
$COCH_3$	*cis*	CCl_4	6·29	(7·3)	6·28	(7·0)	—[f]	7·1–7·3[l]	7·6–7·9	8·2–8·6[o]	2·93 (s)	$NCOCH_3$, 7·82 (s)	JEOL (×5)
		C_6H_6	6·36	(7·2)	6·36	(7·2)	—[f]	7·4–7·7	7·7–8·1	8·5–8·9[o]	—	$NCOCH_3$, 8·03 (s)	JEOL (×5)
	trans	CCl_4	6·38	(11·1)	6·44	(3·5)	(11·9)[g]	7·5–7·8[m]		7·8–9·0[p]	2·88 (s)	$NCOCH_3$, 7·94 (s)	JEOL (×5)
$(CH_3)_2$	*cis*	$CDCl_3$	5·93	(11·2)	5·41	(4·9)	(13·3)	6·9–7·5	7·8–8·8[q]		1·6–2·7	$N(CH_3)_2$, 5·88 (s); 6·06 (s)	Va. (×1)
	trans	$CDCl_3$	6·23	(10·2)	5·40	(2·1)	(12·8)[h]	7·2–7·7[n]	7·8–8·9[q]		1·5–2·7	$N(CH_3)_2$, 5·92 (s); 6·02 (s)	Va. (×1)

[a] Each of the four lines due to H–B is split to a doublet. Discussed later. [b] A line at high field is obscured by the signal due to H-10a. [c] The signal due to H–A is not well resolved. [d] A line at high field is hidden beneath the peak due to the N-methyl protons. [e] Only two prominent peaks at τ 6·94 and 7·07 are observed, and the analysis is disturbed by the signal due to the N-methyl protons. [f] Not determined. [g] The assignment is tentative. [h] The peaks of the N-methyl protons disturb the complete analysis, and thus the assignment is tentative. [i] Quartet or probably quintet. [j] Octet or nonette with equal splittings of 4·4 c/s. [k] Quintet. [l] Quartet. [m] The signals due to H-10a and H-6a are mixed. [n] Triplet with splittings of about 9 cs. [o] Narrow peaks. [p] Wide peaks. [q] The signals due to the ring C protons other than H-10a are mixed. [r] The symbol "s" means singlet. [s] The figures in parentheses refer to "expanded width" of the region where H-6 and/or H-10a appear.

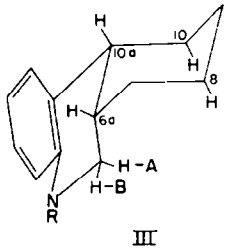
region in question of the *trans* isomer, the expanded spectrum of the *cis* isomer indicated clearly that the four higher field lines were further split by a long range coupling, which will be discussed later.

The coupling constants for the protons 6 of the isomer of m.p. 72° are in agreement with a rigid conformation (II, R = H), in which J_{AX} (~10 c/s) is an ax/ax coupling and J_{BX} (~3·5 c/s) is eq/ax coupling,[10] though the values do not prove the *trans* configuration of the compound. However, the broad signal at τ 8·0 to 9·1 due to the protons of C-ring is typical of cyclohexane protons which are parts of *trans*-fused systems, provided that the number of axial substituents is not great.[11] As compared with the relatively narrow resonance of C-ring protons in the other isomer of m.p. 42°, the broad signal indicates undoubtedly that the compound of m.p. 72° has the B/C *trans* configuration, as described previously.[5]

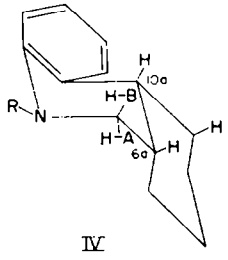


II

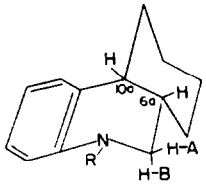
The coupling constants, J_{AX} = ~9·0 c/s and J_{BX} = ~3·5 c/s, for the protons 6 of the *cis* isomer appear to demonstrate that the isomer is largely confined to conformation III (R = H), if the ring B has a half-chair form. An alternate conformation IV (R = H) is ruled out since both the coupling constants J_{AX} (eq/eq) and J_{BX}(ax/eq) would be small (2 to 4 c/s). The conformation III is consistent with our previous assignment on the basis of the UV spectra.[5] However, there is another possibility; namely, the ring B might have a twist-boat conformation (V, R = H). In V, the proton



III



IV



V

[10] All the labellings "equatorial (eq) and axial (ax)" refer to the ring B, unless otherwise stated.

[11] J. Musher and R. E. Richards, *Proc. Chem. Soc.* 230 (1958); J. Musher, *J. Amer. Chem. Soc.* **83**, 1146 (1961); R. L. Clarke, *Ibid.* **83**, 965 (1961); H. Booth, *Tetrahedron* **19**, 91 (1963); H. Feltkamp, N. C. Franklin and W. Kraus, *Liebigs Ann.* **683**, 75 (1965).

proton A is equatorial and almost eclipsed to the proton 6a and thus J_{AX} would be large (8 to 10 c/s).[12] On the other hand, the proton B is axial and has a dihedral angle of about 120°, which would give a small J_{BX}(2 to 4 c/s).[12] Therefore, the twist-boat conformation satisfies the observed coupling constants as well as the half-chair conformation III.

In one of the previous papers,[3] most of the NMR spectra of a number of 1,2,3,4-trahydroquinolines were interpreted successfully by assuming that the reduced nitrogen ring consists mainly of a half-chair conformation. While the energy difference between a twist-boat and a half-chair form in tetrahydroquinoline appears neither to have been calculated nor observed, it would certainly be small as compared with that for cyclohexane (4·9 to 5·5 kcal/mole),[13] since the corresponding difference in cyclohexene is estimated to be 2·2 to 2·7 kcal/mole[14] and tetrahydroquinoline is regarded as an analog of tetralin or cyclohexene rather than cyclohexane. In addition, the bowsprit-flagpole interaction considered to cause the maximum strain in the boat form would be considerably decreased, as the steric effect of the lone pair electrons of a N-atom has been found to be 0·4 kcal/mole smaller than that of a hydrogen atom on a N-atom.[15] In the twist-boat conformation V of the *cis* isomer, the bond (C-6a)–(C-7) is almost eclipsed to the proton B and the extra energy due to the interaction must be considered. However, it would be less than 0·3 kcal/mole (energy difference between the eclipsed forms of propane and ethane). On the other hand, in the half-chair conformation III, an interaction of skew-butane type is added anew, which would be about

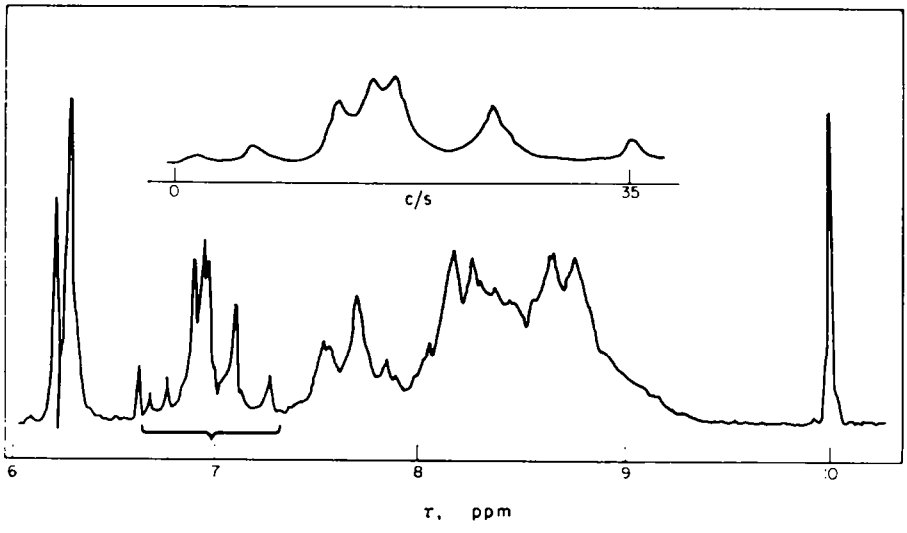


FIG. 1. The NMR spectrum of *trans*-octahydrophenanthridine; solvent, CH_2Cl_2.

[12] H. Conroy, *Advances in Organic Chemistry* Vol. II, p. 311. Interscience, New York, N.Y. (1960).
[13] [a] W. S. Johnson, V. J. Bauer, J. L. Margrave, M. A. Frish, L. H. Dreger and W. N. Hubbard, *J. Amer. Chem. Soc.* **83**, 606 (1961); [b] J. L. Margrave, M. A. Frish, R. G. Bautisa, R. L. Clarke and W. S. Johnson, *Ibid.* **85**, 546 (1963). For calculated values, 5·1, 5·33 and 5·6 kcal/mole were given in the following papers respectively; [c] N. L. Allinger, *Ibid.* **81**, 5727 (1959); [d] J. B. Hendrickson, *Ibid.* **83**, 4537 (1961); [e] C. W. Beckett, K. S. Pitzer and R. Spitzer, *Ibid.* **69**, 2488 (1947).
[14] C. W. Beckett, N. K. Freeman and K. S. Pitzer, *J. Amer. Chem. Soc.* **70**, 4227 (1948).
[15] N. L. Allinger, J. G. D. Carpenter and F. M. Karkowski, *J. Amer. Chem. Soc.* **87**, 1232 (1965).

1·8 kcal/mole. In view of the fact that entropy of a boat form is usually greater than that of a chair form,[16] it is concluded that the conformation V would be as stable as III. Hence, *cis*-octahydrophenanthridine is principally fixed in either the conformation III or V (R = H), as far as the coupling constants of the protons 6 and the stability of the two forms are concerned.

The resonance of the proton A was found at lower field by about 0·3 ppm than that of the proton B. At first thought, this fact appears to support the conformation V as against III, since an axial proton of cyclohexane is usually located at higher field than an equatorial one,[17] as shown in the spectrum of the *trans* isomer (I, R = H). However, in the spectrum of *cis*-N-methyloctahydroacridine, the same situation has been observed.[18] In the conformation III with twin chairs, the proton A would be deshielded, relative to usual axial protons, by the axial protons at positions 8 and 10 because of the van der Waals compression. This deshielding effect is shown in the following simple examples; for 2-*trans*-t-butyl-5-*trans*-methylcyclohexanol, the proton at position 1 appears at τ 6·20,[19] whilst the corresponding proton of 2-*trans*-t-butylcyclohexanol absorbs at τ 6·60.[20] Furthermore, the chemical shifts of the protons on carbon holding a hydroxyl group are τ 6·52, 6·35 and 6·18 for 3-*cis*-methyl-5-*cis*-methyl-, 3-*cis*-methyl-5,5-dimethyl- and 3,3,5,5-tetramethyl-cyclohexanols respectively.[20] Several examples are reported of an effect similar to that mentioned above.[21]

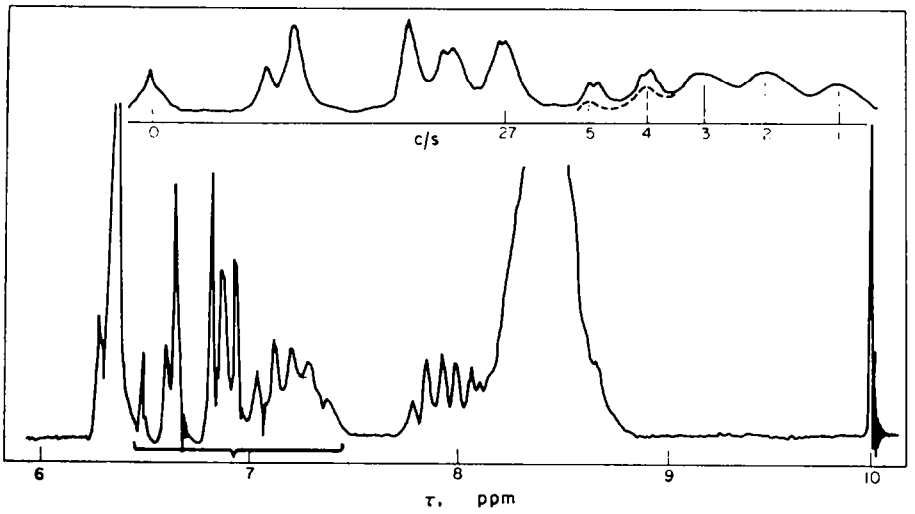


FIG. 2. The NMR spectrum of *cis*-octahydrophenanthridine; solvent, CH_2Cl_2.

[16] cf. N. L. Allinger and L. A. Freiberg, *J. Amer. Chem. Soc.* **82**, 2393 (1960).

[17] The difference of chemical shifts between axial and equatorial protons, which exist on a carbon adjacent to the N-atom in quinuclidine, has been found to be remarkably large (0·94 ppm). H. P. Hamlow, S. Okuda and N. Nakagawa, *Tetrahedron Letters* 2553 (1964).

[18] The axial proton at position 9 of the compound (Formula III of the Ref. 2) is hindered by the axial protons at positions 2 and 4, and appears at 0·45 ppm lower field than the corresponding equatorial proton. See Table of the Ref. 4a.

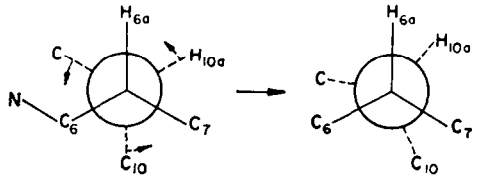
[19] H. Feltkamp and N. C. Franklin, *Tetrahedron* **21**, 1541 (1965).

[20] E. L. Eliel, M. J. Gianni, Th. H. Williams and J. B. Stothers, *Tetrahedron Letters* 741 (1962).

[21] W. Nagata, T. Terasawa and K. Mori, *J. Amer. Chem. Soc.* **86**, 3746 (1964); G. Slomp, Jr. and B. R. McGarvey, *Ibid.* **81**, 2200 (1959).

In the present case, neither the exact magnitude nor the reason for the deshielding effect is known; however, it seems certain that this effect could bring the chemical shift of the proton A lower than that of the proton B, despite the fact the latter is equatorial and the former axial.

Consideration of the resonance of the proton 10a seems to favor the half-chair conformation III rather than the twist-boat form V. The signal due to the proton appeared as three lines with separations of 5 to 6 c/s in both dichloromethane (Fig. 2) and tetrachloromethane solutions. However, it seems certain that there are one or two lines which are hidden beneath the high field lines due to the proton B and thus, the line 4 or 4 and 5 (dotted lines) may be interpolated to make a symmetrical quartet or quintet. If the *cis* amine is fixed in V, then the proton 10a is coupled about *equally* to the three neighbours, since the dihedral angles are all about 60°. Hence, a signal of quartet type, with separations of 2 to 4 c/s, will be expected; this is *roughly* in agreement with the observed signal, if one assumes that the proton forms a quartet. However, the observed splittings appear to be somewhat larger than accepted values for J_{ae} and J_{ee} and, furthermore, the signal in question may not be a quartet but a quintet. In fact, in the spectrum (Fig. 3) of *cis*-N-benzoyloctahydrophenanthridine, which is fixed in a somewhat deformed half-chair conformation III (discussed later), the resonance of the proton 10a was clearly seen as a quintet with separations of 5 to 6 c/s. If the *cis* amine has an undistorted conformation III, the proton 10a is exactly axial with respect to ring C, and is coupled to one axial and two equatorial protons. Therefore, one expects a signal of doublet character with a separation of about 10 c/s, which is in poor agreement with the observed signal. However, the proton 10a is pseudo-equatorial with respect to ring B, and then the dihedral angle between the protons 10a and 6a must be modified; this is most easily appreciated from the projection formulae VI and VII, the view as seen along the bond (C-6a)–(C-10a) being shown, in which VII is a modified formula.



VI VII

In VII, the dihedral angle would become 30 to 40°, which gives the value 5 to 6 c/s for $J_{10a,6a}$. Consideration of models indicates that this deformation brings variation of the dihedral angles between the protons 10a and 10; the value between the protons 10a and 10 (eq) would become 30 to 40° (J = 5 to 6 c/s) and that between those 10a and 10 (ax) 150 to 160° (J = 9 to 11 c/s). From these three coupling constants, one expects a signal of quintet character with separations of 5 to 6 c/s, which agrees well with the observed signal. The deformation as mentioned above seems to be improbable with the boat form V.

As described before, the four lines due to the proton B were each split into a doublet with a separation of 0·7 to 0·8 c/s, showing the existence of a long range coupling. This coupling, which is assumed to be of the four-bond type, (H–B)–(C-6a)–(C)–(H), is only

a coupling with *one* other proton. Now the most common type of four-bond coupling involves the stereochemical arrangement usually called the extended zigzag configuration.[22] In the conformation III, one might expect the proton B to show long range coupling to both the protons 10a and 7 (ax), in which the long range coupling would give rise to a triplet (for the same two couplings) or a quartet (for two different couplings). However, it could be argued that a slight distortion of the ring system might mean that only one of the two protons 10a and 7 (ax) was stereochemically favorable to the coupling. On the other hand, in the conformation V, none of the protons at position 10a or 7 is suitably disposed for the long range coupling by the extended zigzag method.

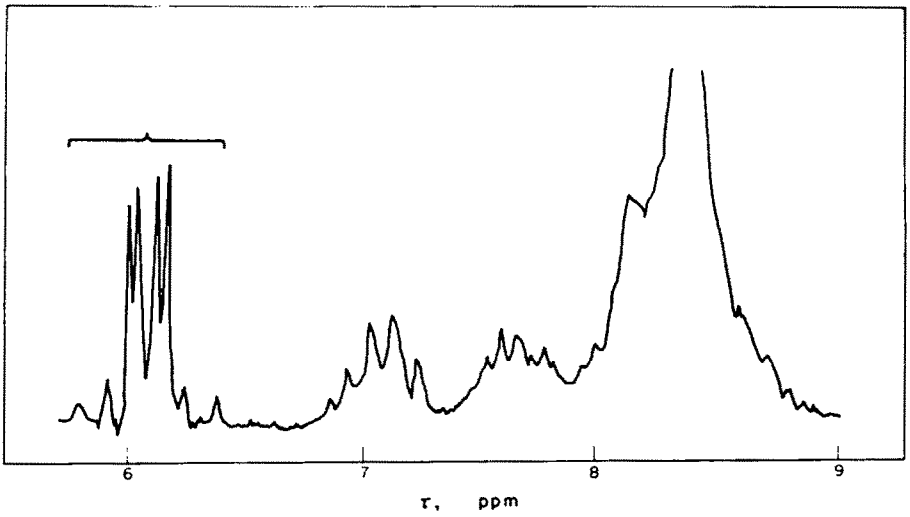


FIG. 3. The NMR spectrum of *cis*-N-benzoyloctahydrophenanthridine; solvent, $CDCl_3$.

In summary, it might be impossible to decide for *certain* between the conformations III and V (R = H) from the available data, but the former seems to be the more acceptable conformation for the *cis* isomer in view of the weight of evidence.

The arguments mentioned on the secondary amine are completely applicable to cis-N-*methyloctahydrophenanthridine* (I, R = CH_3); that is, the NMR spectrum of the tertiary amine in tetrachloromethane was almost superimposable on that of the *cis*-secondary amine in the same solvent, except that the signal due to the proton on the N-atom was replaced by that due to the N-methyl protons.

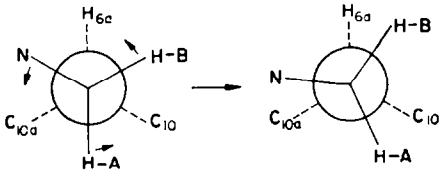
The N-*benzoyl and* N-*acetyl derivatives*

The spectra of the *cis* and *trans* isomers of N-*benzoyloctahydrophenanthridine* (I, R = COC_6H_5) are interesting for two reasons. Firstly, while the signal due to the proton 10a of the *cis* isomer appeared at τ 6·9 to 7·3 as a quintet with separations of 5 to 6 c/s (Fig. 3), the corresponding signal of the *trans* isomer occurred at τ 7·4 to 7·8 as a triplet with splittings of about 9 c/s. This indicates that the *trans* isomer exists

[22] A. Rassat, C. W. Jefford, L. M. Lehn and B. Waegell, *Tetrahedron Letters* 233 (1964); S. Sternhell, *Revs. Pure and Appl. Chem., Austr.* **14**, 15 (1964).

in the rigid conformation II (R = COC_6H_5); the proton 10a is axial in respect to the ring C and coupled to two axial protons 6a and 10 and to one equatorial proton 10. Thus, one expects a signal of triplet character with separations of about 10 c/s, which is consistent with the observed pattern. On the other hand, the signal (quintet) of the *cis* isomer could be interpreted successfully, when the isomer is fixed in a somewhat deformed conformation III, as already described.

Secondly, the resonance of the protons 6 in the spectrum of the *cis* isomer (Fig. 3) consisted of eight lines, due to AB part of ABX system, of *almost the same* type as that of the *trans* isomer, except that the former was shifted as a whole to lower field by about 0·15 ppm than the latter; the central four lines were sharp and had almost equal, strong intensities in contrast with weak out-side lines. As a result, for the coupling constants (J_{AX}, J_{BX} and J_{AB}) and the difference in chemical shifts ($\tau_A - \tau_B$), almost the same values, about 8·0, 6·8 and 12·3 c/s and 0·14 ppm, were obtained for both the *cis* and *trans* isomers. It is noteworthy that (1) the proton A, giving the larger coupling constant to proton 6a, appears at higher field than the proton B, and thus the deshielding effect previously mentioned for conformation III must be small, and (2) both the coupling constants J_{AX} and J_{BX} are larger than accepted values for J_{ae} but are somewhat smaller than accepted values for J_{aa}. These facts indicate that the ring B, especially the system (N)–(C-6)–(C-6a), must be deformed by substitution of a benzoyl group on the N-atom. This deformation is shown by the projection formulae VIII and IX, the view as seen along the bond (C-6)–(C-6a), in which IX is a modified formula.



VIII IX

In IX, the dihedral angle between the protons A and 6a would become 140 to 150°, and that between the protons B and 6a 30 to 40°. This deformation would not only reduce the deshielding effect from the axial proton 10 in the *cis* isomer, but also give the values 8 to 7 c/s for the coupling constants J_{AX} and J_{BX}.[12]

It appears to be impossible to explain the observed spectra successfully in terms of the conformations IV and V or in their modified forms. It is concluded that the *cis* and *trans* isomers of N-benzoyloctahydrophenanthridine are fixed in somewhat distorted modifications of conformations II and III respectively.

In the NMR spectrum of cis-N-*acetyloctahydrophenanthridine* (R = $COCH_3$) in tetrachloromethane, there were only two sharp peaks attributable to the protons 6 at τ 6·34 and 6·22. Although the expanded and intensified spectrum of the region showed that each of the peaks was a doublet, with splittings of 0·8 and 0·5 c/s, no lines regarded as part of the AB portion of an ABX system were seen outside these peaks. This line pattern is typical of the A_2 part of an A_2X system in which A protons are equivalent. The simplification of the ABX to the A_2X system on acetylation is not due to a change in relative chemical shifts caused by a solvent effect,[23] as the simple

[23] R. J. Abraham and H. J. Bernstein, *Canad. J. Chem.* **39**, 216 (1961).

two-line pattern was given in benzene as well as in tetrachloromethane. In benzene, no resolution of each peak was observed even in the expanded spectrum. Analysis shows that both the two protons at position 6 appear at τ 6·29 (in CCl_4) or at τ 6·36 (in C_6H_6), and have an equal coupling with proton 6a of about 7 c/s. This equivalence indicates that *cis*-N-acetyloctahydrophenanthridine may exist as a mixture of rapidly interconvertible conformations III and IV (R = $COCH_3$). On the other hand, the proton 10a clearly appeared at τ 7·1 to 7·3 as a quartet with separations of about 5 c/s in tetrachloromethane. This pattern also supports the conclusion mentioned above, provided that the conformations III and IV are slightly deformed as already described and exist in equal amounts.

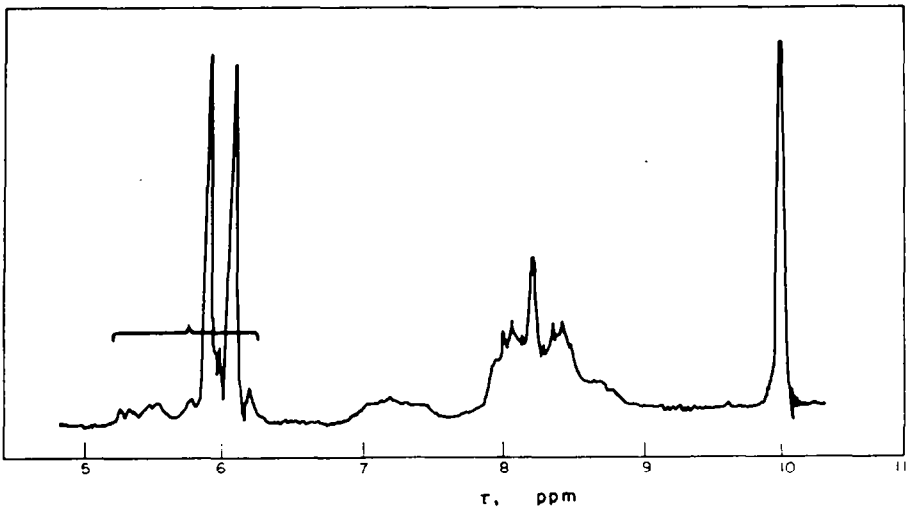
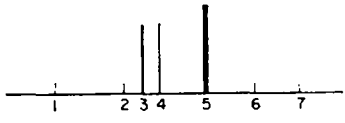


FIG. 4. The NMR spectrum of *cis*-N-methyloctahydrophenanthridine methiodide; solvent, $CDCl_3$.

In the spectrum of trans-N-*acetyloctahydrophenanthridine*, the signal due to the protons 6 did not show a clear eight-line pattern, and only three prominent peaks appeared at τ 6·52, 6·42 and 6·39 (lines 5, 4 and 3 in the following scheme), the ratio of intensity being 2, 1 and 1, along with weak peaks at τ 6·62 and 6·35 (lines 6 and 2)



Thus, the spectrum was analysed, assuming that (1) the resonance of the protons 6 constitutes the AB part of an ABX system, and (2) very weak peaks exist at τ 6·73 and 6·20 (lines 7 and 1), though not clearly seen, and (3) the signal due to one of the two protons is resolved into a quartet of lines 1, 2, 3 and 5, and that of the other into a quartet of lines 4, 5, 6 and 7. Accordingly, the result of analysis is tentative, but the values obtained for J_{AX} (11·1 c/s) and J_{BX} (3·5 c/s) indicate that the *trans* isomer is fixed in the conformation II (R = $COCH_3$).

The quaternary iodides

The spectrum of cis-N-*methyloctahydrophenanthridine methiodide* was not very well resolved because of the low solubility in deuterochloroform and, in addition, two

strong peaks due to the N-methyl protons partly obscured the signal due to the protons 6. Nevertheless, seven of eight lines given by the AB part of an ABX system were seen at τ 5·2 to 6·2, and the remaining one appeared as a shoulder on the peak due to the N-methyl protons (Fig. 4). Analysis of the octet gave $J_{AX} = 11{\cdot}2$ c/s and $J_{BX} = 4{\cdot}9$ c/s, which correspond to J_{aa} and J_{ae}. This suggests that the *cis*-methiodide is fixed in conformation III, and this is confirmed by examination of the signal due to the proton 10a. The signal appeared as a broad peak at τ 6·9 to 7·5 with the half-band width of about 20 c/s, indicating inclusion of an ax/ax coupling, which excludes the possibility of the boat form V. This assignment is also reasonable from a consideration of stability, since substitution of two methyl groups on the N-atom causes a 1,3-diaxial interaction between the methyl group and the methylene group at position 6a, if the *cis*-methiodide has the conformation IV, or results in the serious bowsprit-flagpole interaction between the methyl group and the hydrogen 10a, if it has the boat form V. In addition, the fact that *cis*-methiodide is fixed in the conformation III rather than IV provides an explanation of the observation[5] that thermal decomposition of the derived methohydroxide failed to cause any β-elimination, and merely led to methanol-extrusion.

In the spectrum of trans-N-*methyloctahydrophenanthridine methiodide*, only six lines were seen as the signal due to the protons 6, and the remaining two lines would probably be hidden beneath the peaks due to the N-methyl protons. Therefore, the resonance pattern was analysed in a way similar to that for the *trans*-N-acetyl derivative, and tentative values $J_{AX} = 10{\cdot}2$ c/s and $J_{BX} = 2{\cdot}1$ c/s were obtained. On the other hand, the signal due to the proton 10a appeared at τ 7·2 to 7·7 as a triplet with splittings of about 9 c/s, each peak being slightly broad. This pattern is typical of the proton which suffers two ax/ax and one ax/eq couplings. Both the values J_{AX} and J_{BX} and this resonance pattern confirm that the *trans*-methiodide is fixed in the conformation II. It is of interest that the proton A always appears at higher field than the proton B in both the *trans*- and *cis*-methiodides, but the difference of the chemical shifts ($\tau_A - \tau_B$) is decreased from 0·83 ppm to 0·52 ppm, in passing from the *trans* to the *cis* isomer, indicating the deshielding effect. Futhermore, it is to be noted that the signal due to the ring C protons is not so narrow in the *cis*-methiodide as that in the other *cis* compounds examined in the present investigation, and is indeed as wide as that in the *trans*-methiodide.