was filtered off, the acidic solution was cooled and carefully made strongly basic with NaOH and extracted with ether, the ether extract was dried over KOH, and the solvent was evaporated. The yields of products were determined by vpc (columns: 20% Carbowax 20 M + 10% KOH on Chromosorb W or 30% SE 30 on Chromosorb W). Decahydro and 1,2,3,4-tetrahydro compounds were separated, if necessary (see Table I), by

Table I

Starting Material	Yield of 5,6,7,8-tetrahydro product, %	Mp of picrate, °C, (lit.)
Quinoline	70[a]	159–160 (158–159[b])
2-Methylquinoline	95	158–159 (154[c])
3-Methylquinoline	98	182–183 (182–183[b])
6-Methylquinoline	53[d]	161–162 (159.5–160.5[e])
8-Methylquinoline	55[f]	126–127 (125–126[e])
Isoquinoline	95	143–144 (144[g])

[a] 6% $\Delta^{1,9}$-octahydroquinoline, 24% *cis*-decahydroquinoline. [b] E. Breitmaier and E. Bayer, *Tetrahedron Lett.*, 3291 (1970). [c] See ref 2. [d] 8% starting material, 15% octa- and decahydro, and 24% 1,2,3,4-tetrahydro product. [e] T. Ishiguro, Y. Morita, and K. Ikushima, *Yakugaku Zasshi*, **79**, 1073 (1959). [f] 10% starting material, 12.5% octa- and decahydro, and 22.5% 1,2,3,4-tetrahydro product. [g] R. Grewe and A. Mondon, *Ber.*, **81**, 279 (1948).

dissolving the mixture of products in 100 ml of dry acetone, adding acetic anhydride and potassium carbonate, and refluxing overnight. After dilution with ether, the salts were filtered off, the solvents were evaporated, and the residue was dissolved in 6 *N* HCl and extracted with ether. (From the ether solution the amides can be recovered and cleaved with concentrated HCl.) The aqueous solution was made strongly basic, and the 5,6,7,8-tetrahydroquinoline or -isoquinoline was extracted with ether, dried, distilled under reduced pressure, and characterized by nmr spectrum and melting point of picrate.

Using this procedure, yields of 5,6,7,8-tetrahydroquinolines shown in Table I were attained.

When the reaction time is sufficient to reduce all starting material, the by-products are readily removed by acetylation, as described above.

From the 5,6,7,8-tetrahydroquinolines it is easy to prepare, by means of sodium–ethanol reduction,[2,5] the otherwise not very readily available *trans*-decahydroquinolines. The products can be isolated by crystallization, if solid, or by preparative gas chromatography, using the columns described above. The *trans*-decahydroquinolines so prepared are listed in Table II. Configurational assignments are evident from the pmr spectra[6] and are confirmed by the cmr spectra;[7] a complete discussion of these data will be given in the full paper.

We are presently studying variations in catalyst and reaction medium designed to optimize yields and to reduce reaction times if possible. Preliminary results in reduction of quinoline over platinum oxide using 12 *N* sulfuric acid as a solvent indicate that 5,6,7,8-tetrahydroquinoline may be obtained in 74% yield in 4.5 hr; use of trifluoroacetic acid leads to 5,6,7,8-tetrahydroquinoline in 84% yield after only 45 min.

(5) R. L. Augustine, "Reduction," Marcel Dekker, New York, N. Y. 1968, p 135.
(6) *Cf.* ref 3 for *trans*-decahydroquinoline.
(7) *Cf.* H. Booth and D. V. Griffiths, *J. Chem. Soc., Perkin Trans. 2*, 842 (1973) for *trans*-decahydroquinoline.

Table II

Starting 5,6,7,8-tetrahydroquinoline	Product *trans*-decahydroquinoline	Yield,[a] %
Unsubstituted	Unsubstituted[b]	90
3-Methyl	3-α-methyl (equatorial)[c,d]	60
	3-β-methyl (axial)[c]	30
8-Methyl	8-α-methyl (equatorial)[c,e]	50
	8-β-methyl (axial)[c,e]	40

[a] Determined by vpc. [b] Mp 48° (petroleum ether) (lit.[3] 48–48.5°). [c] β means "on the same side as the hydrogen at the proximal ring junction," α "on the opposite side from this hydrogen;" *cf.* E. L. Eliel, N. L. Allinger, S. J. Angyal, and G. A. Morrison, "Conformational Analysis," Interscience, New York, N. Y., 1965, p 89. [d] Mp 81° (petroleum ether); a melting point of 70–71° is reported for an unspecified mixture of 3-methyldecahydroquinolines (ref 2). [e] Elemental analysis agreed with theory.

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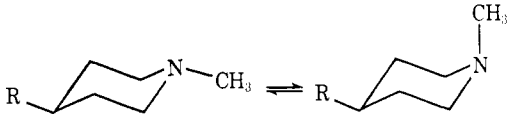
High Equatorial Preference of the *N*-Methyl Group in *N*-Methyl-*trans*-decahydroquinoline

Sir:

Comparison of the conformational equilibrium of the *N*-methyl group in an *N*-methylpiperidine (Scheme I,

Scheme I



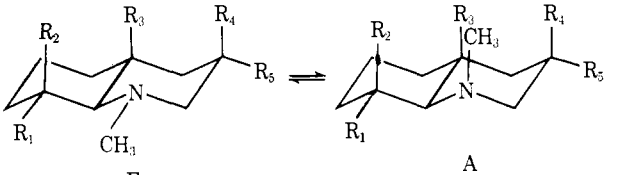
1

R = H) with the known equilibrium in methylcyclohexane ($\Delta G°$ = 1.7 kcal/mol[1]) is of considerable interest. The $\Delta G°$ value for **1** was originally assessed[2] by a dipole moment measurement on 4-*p*-chlorophenyl-*N*-methylpiperidine (Scheme I, R = *p*-ClC_6H_4) as 1.6–1.7 kcal/mol, essentially identical with the methylcyclohexane value. However, it later appeared[3] that, because of an error in the measurement of the reference moment (*p*-chlorophenylcyclohexane), the calculated value was too high, and recent dipole measurements, using *p*-chlorophenyl and *p*-nitrophenyl (Scheme I, R = *p*-$O_2NC_6H_4$) 4-substituted *N*-methylpiperidines, have yielded a value for $\Delta G°$ of 0.53–0.81 kcal/mol;[4] this value seems to have been accepted by others,[5] even though it appears surprisingly small and even though interpretation of Bohlmann band measurements in the

(1) E. L. Eliel, N. L. Allinger, S. J. Angyal, and G. A. Morrison, "Conformational Analysis," Interscience, New York, N. Y., 1965.
(2) N. L. Allinger, J. G. D. Carpenter, and F. M. Karkowski, *J. Amer. Chem. Soc.*, **87**, 1232 (1965); R. J. Bishop, L. E. Sutton, D. Dineen, R. A. Y. Jones, and A. R. Katritzky, *Proc. Chem. Soc., London*, 257 (1964).
(3) R. J. Bishop, L. E. Sutton, D. Dineen, R. A. Y. Jones, A. R. Katritzky, and R. J. Wyatt, *J. Chem. Soc. B*, 493 (1967).
(4) R. A. Y. Jones, A. R. Katritzky, A. C. Richards, and R. J. Wyatt, *J. Chem. Soc. B*, 122 (1970). The most recently published value—I. D. Blackburne, R. P. Duke, R. A. Y. Jones, A. R. Katritzky, and K. A. F. Record, *J. Chem. Soc., Perkin Trans. 2*, 332 (1973)—based on "optimized geometry" is 0.65 kcal/mol.
(5) See, *e.g.*, J. B. Lambert, D. S. Bailey, and B. F. Michel, *J. Amer. Chem. Soc.*, **94**, 3812 (1972).

infrared[6] as well as quenching experiments in trifluoroacetic acid[7] led to a much higher value of $\Delta G^\circ \geq 1.6$ kcal/mol for the *N*-methyl group. It thus appeared that the determination of the conformational equilibrium in Scheme I (R = H) would bear reexamination.[8] Successful synthesis, in our laboratory, of a variety of *trans*-decahydroquinolines[9] (Scheme II) and examination of their ^{13}C spectra provided a good handle for examining the *N*-methyl(equatorial) $\rightleftharpoons$ *N*-methyl(axial) equilibrium shown in Scheme II. It might be noted that the N–Me(e) isomer in **2** and **3** has one peri interaction more than *N*-methylpiperidine (1 *vs.* 0), whereas the N–Me(a) isomer has one syn-axial interaction more (3 *vs.* 2). Since, to a good approximation, peri- and syn-axial interactions are equivalent, the ΔG°_{Me} values for **2** and **3** in Scheme II should be similar to the ΔG°_{Me} value in *N*-methylpiperidine (Scheme I).

Scheme II



E A

2, $R_1 = R_2 = R_3 = R_4 = R_5 = H$
3, $R_1 = R_2 = R_3 = R_4 = H$; $R_5 = CH_3$
4, $R_1 = R_3 = R_4 = R_5 = H$; $R_2 = CH_3$
5, $R_1 = R_2 = R_4 = R_5 = H$; $R_3 = CH_3$
6, $R_1 = R_2 = R_3 = R_5 = H$; $R_4 = CH_3$
7, $R_2 = R_3 = R_4 = R_5 = H$; $R_1 = CH_3$

Table I summarizes the *N*-methyl cmr shifts for compounds **2**–**7**. The *N*-methyl signals in **2**–**6** are very easy to assign on the following basis: in *trans*-decahydroquinoline,[9,10] C-2 and C-9 are far downfield from all other carbons. N-Methylation shifts these signals even further downfield by a β_e effect.[11] The shifted signals are easy to discern, and the only other downfield signal corresponds to the *N*-methyl group.

Table I

Compound	*N*-Methyl shift[a]	Compound	*N*-Methyl shift[a]
2	42.63	**5**[b]	43.15
3	42.43	**6**	43.05
4	42.33	**7**	33.27

[a] In ^{13}C spectrum, solvent $CDCl_3$, in ppm downfield from TMS. Similar values are obtained in benzene-d_6. [b] For preparation of 10-methyl-*trans*-decahydroquinoline, see T. Henshall and E. W. Parnell, *J. Chem. Soc.*, 661 (1962).

The only compound for which *N*-methyl assignment was difficult is **7**. The axial *N*-methyl group in **7** is shifted considerably upfield and occurs very near several other signals. Unequivocal identification was made by synthesis of the N–CD_3 analog of **7**; the broad-band decoupled ^{13}C spectrum of this compound shows all other ten signals unchanged, but the *N*-methyl signal at 33.27 ppm disappears through loss of the nuclear Overhauser enhancement and by being split into a heptet. Additional information was gained by specific proton decoupling of the N–CH_3 protons of **7** (δ 2.23 ppm in the pmr spectrum), which decouples the cmr peak at 33.27 ppm, and by off-resonance decoupling, which shows the *N*-methyl and high field *C*-methyl groups as quartets.

It should be noted that compounds **2** and **3** have essentially "unperturbed" (except for the peri interaction, see above) methyl groups, which should assume an equatorial–axial equilibrium (Scheme II, E $\rightleftharpoons$ A) similar to **1**. The *N*-methyl signals in **2** and **3** are accordingly very close to each other, with an average shift of δ 42.53 ppm. In compounds **4**, **5**, and **6** one would expect E (Scheme II) to be the exclusive conformation, since in A there would be severe syn-axial Me/Me interactions between N–Me and R_2, R_3, and R_4. Thus these compounds provide the shift for the equatorial *N*-methyl group, averaged from **5** and **6** as δ_e 43.10 ppm.[12] Finally, **7** is expected to exist entirely in conformation A because of severe peri-Me/Me interaction in 7E.[12] Thus the N–Me shift of **7** may be taken as a measure of the axial N–Me shift, δ_a 33.27.

Using the equation[1] $K = (\delta_e - \delta)/(\delta - \delta_a)$ one may calculate $K = 0.062$ whence $\Delta G^\circ = 1.65$ kcal/mol. This value agrees with the values of Tsuda and Kawazoe[6] and of Booth and Little[7] and disagrees with the much lower values published by Katrizky's group.[3,4] It is insignificantly smaller than the corresponding value in methylcyclohexane.

From earlier work[13] we assess the uncertainty in the measurement of ^{13}C shifts plus the systematic uncertainty in the choice of models as ± 0.5 ppm. If we assume δ to be 0.5 ppm lower than indicated above, K would be 0.122 and $\Delta G^\circ = 1.25$ kcal/mol, still well above the value of ref 4. We consider this to be an outside reasonable limit.

Finally, in transferring these values to *N*-methylpiperidine itself (Scheme I), we note, quite apart from the conformational analogy pointed out earlier, that the N–Me signal in *N*-methylpiperidine[14] comes at 46.9 ppm, in *N*,3-dimethylpiperidine[15] at 46.8 ppm and in *N*,*cis*-3,5-trimethylpiperidine at 46.4[15] or 46.6[10] ppm, whereas that in *N*,3,3-trimethylpiperidine[15] lies at 47.1 and that of *N*,*trans*-3,5-trimethylpiperidine at 47.2[15] or 47.4[10] ppm. The signals of the latter two compounds must refer to purely equatorial N–Me (because of syn-axial Me/Me repulsion in the axial N–Me conformation) whereas the former three values refer to mobile N–Me.

(6) M. Tsuda and Y. Kawazoe, *Chem. Pharm. Bull.*, **16**, 702 (1968).
(7) H. Booth and J. H. Little, *J. Chem. Soc., Perkin Trans. 2*, 1848 (1972). Value for *N*,*cis*-3,5-trimethylpiperidine.
(8) We note that the discrepancy in the reported ΔG° values for **1** (*ca.* 1 kcal/mol) is considerably larger than the corresponding variation for piperidine itself, for which the NH(e) $\rightleftharpoons$ NH(a) equilibrium has been reported to range over 0.6 kcal/mol (0 $\pm$ 0.3 kcal/mol); yet the piperidine problem has received a great deal more attention than the *N*-methylpiperidine one.
(9) F. W. Vierhapper and E. L. Eliel, *J. Amer. Chem. Soc.*, **96**, 2256 (1974). The *N*-methyl derivatives were produced from the parent compounds with HCOOH–CH_2O. All new compounds gave satisfactory elemental analyses.
(10) H. Booth and D. V. Griffith, *J. Chem. Soc., Perkin Trans. 2*, 842 (1973).
(11) D. K. Dalling and D. M. Grant, *J. Amer. Chem. Soc.*, **89**, 6612 (1967); **94**, 5318 (1972).
(12) Slight distortions may cause **4** to have its *N*-methyl signal upfield from **5** and **6**. It might be noted that averaging in **4** for calculation of $\delta_{N-Me_{eq}}$ or assuming that the N–Me group in **7** is not totally axial would further increase the calculated value for the N–Me conformational equilibrium (see below).
(13) A. K. Jones, E. L. Eliel, D. M. Grant, M. C. Knoeber, and W. F. Bailey, *J. Amer. Chem. Soc.*, **93**, 4772 (1971).
(14) M. W. Duch, Ph.D. Thesis, University of Utah, 1970.
(15) D. W. Cochran, Ph.D. Thesis, Indiana University, Bloomington, Ind., 1971; L. D. Kopp, Ph.D. Thesis, University of Notre Dame, Notre Dame, Ind., 1973.

Unfortunately, a reference value for purely axial N–Me in the *N*-methylpiperidine series is not available, but it seems likely that this signal, because of the usual van der Waals (γ_a) shift[10,11] should be at least 6 ppm upfield from the equatorial N–Me signal (note in Table I that the difference is 10 ppm in the *N*-methyl-*trans*-decahydroquinolines so 6 ppm is a very conservative estimate).[16] With this premise, *N*-methylpiperidine would have at least 90% equatorial *N*-methyl, *i.e.*, at best slightly less than *N*-methyl-*trans*-decahydroquinoline.[17,18]

(16) The difference between the N–Me signals in *N*,*N*,3-trimethylpiperidinium iodide is 9.0 ppm.[15]

(17) The *N*-methyl signal of 4-*p*-chlorophenyl-*N*-methylpiperidine (sample kindly supplied by Dr. Allinger) is at 46.41 ppm, *i.e.*, nearly at the same place as that of 4-phenyl-*N*-methylpiperidine, 46.39 ppm;[18] we conclude that, contrary to the calculation based on dipole measurements,[3,4] the *p*-chlorophenyl compound also exists with largely equatorial *N*-methyl. Since it seems unlikely that the several experimental dipole measurements[3,4] are all subject to the same error, the only plausible suggestion we can make is that there is a systematic problem in the calculation of the dipoles for the 4-arylpiperidine models with equatorial and axial N–Me.

(18) A. J. Jones, A. F. Casy, and K. M. J. McErlane, *Can. J. Chem.*, **51**, 1782 (1973).

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Reinvestigation of *E*/*Z* Diastereomerism in Imidates

Sir:

In a recent publication Moriarty, *et al.*,[1] reported that open chained O-methyl imidates and large-membered cyclic lactime ethers were configurationally homogeneous existing in the *Z* ("anti") configuration.[2,3] The configurational instability of the *E* isomers was attributed to interorbital electron repulsion between the nonbonding electrons on oxygen and the lone pair on nitrogen of the imino group in the ground state. The same destabilizing interaction in the transition state should cause a high barrier to inversion at nitrogen ($\Delta G^{\ddagger} > 23$ kcal mol^{-1}). No long-range homoallylic coupling was observed in the nmr spectra of these compounds.

The large long-range spin–spin coupling in imines is a useful tool for the determination of the *E*/*Z* configuration.[4] Thus the five-bond coupling of the *C*-methyl protons to the *N*-methyl protons directly attached to the carbon–nitrogen double bond is much greater when the configuration of the coupling nuclei is "trans" than "cis"[5-7] (*e.g.*, $^5J_{trans}$ = 1.3 Hz and $^5J_{cis}$ = 0.7 Hz in *N*-isopropylidenemethylamine).[7] Analogously, coupling constants of $^5J_{trans}$ = 1.4 Hz and $^5J_{cis}$ = 0.6 Hz are also observed in *N*-methyl thioacetimidate–*S*-methyl ester and –*S*-phenyl ester,[8] in agreement with a $^5J_{trans}$ value of 1.61 Hz in 2-methylthiazoline.[9]

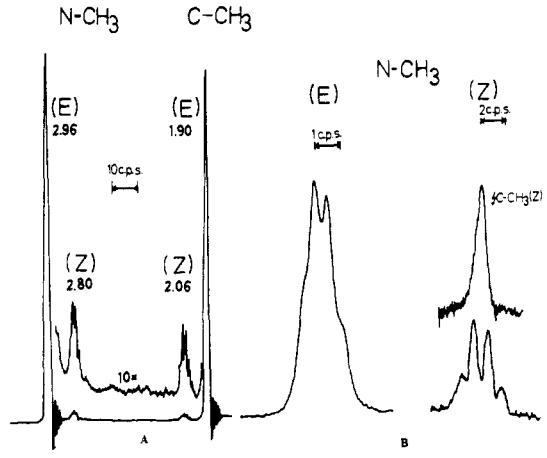
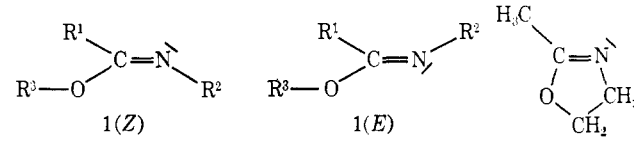


Figure 1. Nmr spectra of the N–CH_3 and C–CH_3 resonances of **1a** in CD_3OD (A) and decoupling of the N–CH_3 (*Z*) quadruplet (B).

We now report the homoallylic coupling between the hydrogens in R^1 and R^2 separated by five bonds in the open-chain acetimidates **1a**, **1b**, **1c**, and 2-methyloxazoline (**2**),[9] leading to the opposite signal assignment than that reported by Moriarty, *et al.*[1] It is known that **1c** exists in the *E* and *Z* isomers.[10] We have found that **1d** exhibits the same isomerism and that also **1a** and **1b** show a small amount of *Z* isomers in methanol (Table I, Figure 1).



1a, $R^1 = R^2 = R^3 = CH_3$[11]
b, $R^1 = R^3 = CH_3$; $R^2 = C_2H_5$[11]
c, $R^1 = R^2 = CH_3$; $R^3 = C_6H_5$[10]
d, $R^1 = t\text{-}C_4H_9$; $R^2 = R^3 = CH_3$[12]

Each of the *C*-methyl resonances of R^1 of **1a**, **1b**, **1c**, and C–CH_3 of **2** showed the expected long-range coupling to the corresponding *N*-alkyl protons and *vice versa* (*e.g.*, N–CH_3 signals of **1a**, Figure 1B). Thus irradiation of the C-methyl resonances resulted in the collapse of the coupling *N*-alkyl resonances.

Further support for the signal assignment derived from the long-range coupling is obtained by using Lanthanide shift reagents.[13] Both signals R^2 and R^3 are strongly shifted when Eu(DPM)$_3$ or Pr(DPM)$_3$ is added to carbon tetrachloride solutions of **1a** and **1d**, while proton signals of R^1 are less affected (imidate **1a**: upfield shift, ratio Pr(DPM)$_3$/**1a** = 0.048, C–CH_3 (0.40 ppm), N–CH_3 (1.00 ppm), O–CH_3 (1.10 ppm); downfield shift, ratio Eu(DPM)$_3$/**1a** = 0.048,

(1) R. M. Moriarty, C. L. Yeh, K. C. Ramey, and P. W. Whitehurst, *J. Amer. Chem. Soc.*, **92**, 6360 (1970).

(2) For a review see (a) C. G. McCarty in "The Chemistry of the Carbon Nitrogen Double Bond," S. Patai, Ed., Interscience, London, 1969, p 363; (b) H. Kessler, *Angew. Chem.*, **82**, 237 (1970).

(3) Concerning the *E*/*Z* nomenclature see J. E. Blackwood, C. L. Gladys, K. L. Loening, A. E. Petrarca, and J. E. Rush, *J. Amer. Chem. Soc.*, **90**, 509 (1968).

(4) S. Sternhell, *Rev. Pure Appl. Chem.*, **14**, 15 (1964).

(5) D. Wurmb-Gerlich, F. Vögtle, A. Mannschreck, and H. A. Staab, *Justus Liebigs Ann. Chem.*, **708**, 36 (1967).

(6) K. Tori, M. Ohtsuru and T. Kubota, *Bull. Chem. Soc. Jap.*, **39**, 1089 (1966).

(7) D. A. Nelson and R. L. Atkins, *Tetrahedron Lett.*, 5197 (1967).

(8) W. Walter and C. O. Meese, more results will be given in a later communication.

(9) M. A. Weinberger and R. Greenmalgh, *Can. J. Chem.*, **41**, 1038 (1963).

(10) M. Kandel and E. H. Kordes, *J. Org. Chem.*, **32**, 3061 (1967).

(11) H. Bredereck, F. Effenberger, and E. Henseleit, *Chem. Ber.*, **98**, 2754 (1965).

(12) The new compound **1d** was prepared from *N*-methyl pivaloimidochloride and sodium methanolate: K_p = 123°; $n^{18}D$ 1.4290; ir(film) $\nu_{C=N}$ 1674 cm^{-1}. Satisfactory analytical data have been obtained for all imidates **1***a*–*d* and **2**.

(13) J. P. Bégué, *Bull. Soc. Chim. Fr.*, **5**, 2073 (1972); (b) R. v. Ammon and R. D. Fischer, *Angew. Chem.*, **84**, 737 (1972).