

THREE-DIMENSIONAL STRUCTURES OF STEREOISOMERS OF 2-PHENYL-
4-ETHYNYLDECAHYDRO-4-QUINOLINOL

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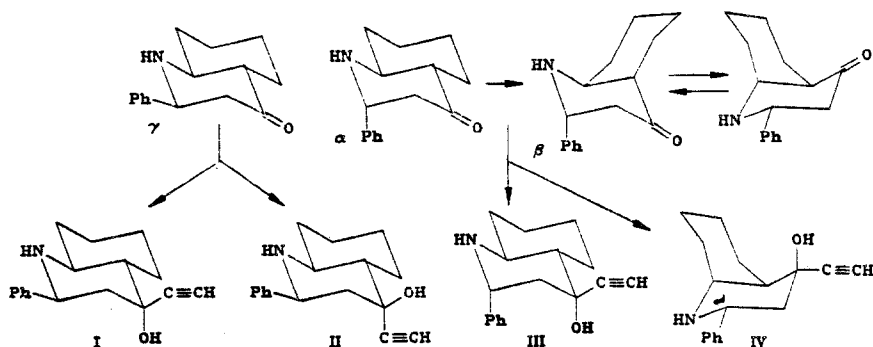
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The three-dimensional structures of four stereoisomers of 2-phenyl-4-ethynyldecahydro-4-quinolinol were determined by PMR and IR spectroscopy. The IR spectra of axial alcohols with an axial γ substituent provide evidence for the existence of two equilibrium forms in solution.

Four stereoisomers of 2-phenyl-4-ethynyldecahydro-4-quinolinol (I-IV) were isolated in the ethynylation of the α and γ forms of 2-phenyldecahydro-4-quinolinone [1]. The configurations of the starting amino ketones consist of trans-fused rings with an axial phenyl group for the α form and an equatorial phenyl group for the γ form [2].

In establishing the structures of the alcohols one must know the orientations of the substituents attached to the $C(2)$ and $C(4)$ atoms as well as the way in which the rings are fused. The orientation of the phenyl group was determined from the vicinal spin-spin coupling constants (SSCC) of the 2-H and 3-H protons. The orientations of the substituents attached to the $C(4)$ atom in the epimeric pair of alcohols I and II were established from the frequency of the stretching vibrations of the OH group [3] and the position of the signal of the proton of the ethynyl group [4]. In alcohols III and IV the orientation of the hydroxy group was found from the change in the chemical shifts of the protons of the piperidine ring when chloroform was replaced by pyridine [5, 6]. The ring fusion was determined from an analysis of the spin-spin coupling (SSC) of the angular protons with the adjacent protons.

The PMR and IR spectra of I-IV are presented in Table 1. The signal of the 2-H proton in the spectra of all of the alcohols is located separately from the other signals, and this makes it possible to easily determine the vicinal constants, from the values of which one can form a judgment regarding the orientation of the substituent attached to $C(2)$ atom. The results obtained indicate an equatorial orientation of the phenyl group in alcohols I, II, and IV and an axial orientation of the phenyl group in alcohol III.



All of the alcohols except IV retain the conformations of the starting ketones. This is confirmed by the fact that in the spectra of trans-fused decahydroquinolinols I-III the signal of the 9-H proton is observed in the form of a triplet (10.0 Hz) of doublets (~3.5 Hz). The multiplet of the proton in the spectrum of alcohol IV is a doublet (12.0 Hz) of triplets (4.0 Hz). The existence of one large constant corresponding to coupling of the trans-

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TABLE 1. PMR and IR Spectra of I-IV

Com- pound	Solvent	PMR spectrum, ppm (TMS)						SSCC, Hz			IR spectrum ν_{OH} ($\Delta\nu_{1/2}$), cm ⁻¹
		2-H	3-H _a	3-H _e	C≡CH	9-H	Ph	2-H, 3-H _a	2-H, 3-H _e	3-H _a , 3-H _e	
I	C ₅ D ₅ N	4.43	2.07	2.40	3.10	3.03	7.26	11.0	3.0	13.0	3622 (16)
	(CD ₃) ₂ C=O	4.05	1.90	2.07	2.74	2.78	7.28	11.0	3.0	13.0	
II	C ₅ D ₅ N	4.23	2.08	2.49	3.37	—	7.26	11.5	2.6	12.5	3618 (16)
	(CD ₃) ₂ C=O	3.99	1.64	2.07	2.96	2.61	7.28	11.5	2.6	12.5	
III	C ₅ D ₅ N	4.29	2.46	2.95	3.17	3.16	—	6.2	2.2	14.0	3616 (16)
	CDCl ₃	4.23	2.35	2.70	2.35	2.85	7.27	6.0	2.2	14.5	
IV	$\Delta\delta$	0.06	0.11	0.25	0.82	0.31	—	—	—	—	3583 (28)
	C ₅ D ₅	4.47	2.08	2.19	2.71	3.15	—	9.7	4.0	13.5	
	CDCl ₃	4.25	2.00	2.00	2.35	3.11	7.27	7.0	7.0	—	
	$\Delta\delta$	0.22	0.08	0.19	0.36	0.04	—	—	—	—	

oriented 9-H and 8-H_a protons and of two identical constants (4.0 Hz) indicating coupling of the 9-H and 8-H_e and 9-H and 10-H-protons in the gauche fragments means that the 9-H proton in IV is axially oriented with respect to the carbocycle and equatorially oriented with respect to the heteroring. The 10-H proton should consequently be equatorially oriented relative to the carbocycle and axially oriented relative to the heteroring. The constants that we found provide evidence for cis fusion of the rings in IV. The correctness of the assignment of the multiplet to the 9-H proton is confirmed by the fact that in the spectrum of alcohol IV it is located at weak field as compared with the other signals, except for the signals of the 2-H and phenyl ring protons, as well as by the fact that in the case of protonation of this alcohol this multiplet and the quartet of the 2-H proton experience the greatest weak-field shifts.

Thus alcohol III with an unchanged configuration is formed from trans-2-phenyldecahydro-4-quinolinone, which has an axial phenyl group. The formation of cis-alcohol IV from the α ketone is evidently explained by its isomerization to the β ketone with cis fusion of the rings (see the scheme) under strongly alkaline ethynylation conditions.

The vicinal constants that we found indicate that alcohols I and II obtained from the γ -keto amine differ only with respect to the orientation of the substituents attached to the C(4) atom. The orientation was determined by using the following rules for the epimeric pair of alcohols: the frequency of the stretching vibrations of an axial OH group is 2-7 cm⁻¹ higher than that of an equatorial OH group [3], and the proton of an axial ethynyl group resonates at weaker field by 0.1-0.2 ppm as compared with the proton of an equatorial ethynyl group [4]. The differences in the frequencies of the vibrations of the OH group and the chemical shifts of the ethynyl protons make it possible to conclude that the OH group in alcohol I is axial, whereas the OH group in alcohol II is equatorial.

The determination of the orientation of the hydroxy group in alcohols III and IV, which are not an epimeric pair, was made from the change in the chemical shifts of the 2-H and 3-H protons when the solvent was replaced. It is known that in the case of an axial orientation of the OH group the deshielding of the axial 2-H proton by pyridine relative to chloroform is 0.2-0.4 ppm. The deshielding of the 3-H proton vicinally oriented relative to the hydroxy group is greater, the smaller the dihedral angle between them. The changes observed in the PMR spectra when the solvent is replaced are due to anisotropy of the magnetic susceptibility of the pyridine ring, which is oriented in a definite way relative to the dissolved alcohol molecule as a consequence of the formation of an OH...N intermolecular hydrogen bond [5, 6]. On the basis of these indications and the $\Delta\delta$ values (Table 1) it may be concluded that the OH group in alcohols III and IV is axially oriented.

The signal of the 9-H proton should experience the same changes as the signal of the 2-H proton when CDCl₃ is replaced by C₅D₅N under the condition that both protons have the same orientation relative to the plane of the piperidine ring. In fact, the axial 9-H proton in III, like the 2-H proton in IV, experiences significant deshielding, while deshielding of the equatorial 9-H proton in IV, like the 2-H proton in III, is not very large. This method of determining the orientation of the hydroxy group could not be applied to alcohols I and II because of their limited solubility in chloroform.

We obtained additional information regarding the orientation of the OH group, its interaction, and the existence of rotational isomers in solution by studying the IR spectra of these compounds and drawing upon the literature data. One narrow absorption band, which is characteristic for a free hydroxy group, is observed in the spectra of dilute solutions of alcohols I and II in CCl_4 in the OH region. In addition to this band, the spectra of alcohols III and IV contain an additional band, which appears in the form of a shoulder in the spectrum of III, whereas in the spectrum of IV it merges with the principal band to form a slightly broadened band with one maximum. The appearance of a second band constitutes evidence that two equilibrium forms exist in solution; their relative amounts do not depend on the concentration but are determined by intramolecular forces and the nature of the solvent.

The same thing was observed in a study of the three-dimensional structures of the stereoisomers of 2-(2-furyl)-4-ethynyldecahydro-4-quinolinol (V) and its N-methyl derivative (VI), as well as 1-methyl-2-(2-furyl)-4-ethynyl-6-phenyl-4-piperidinol [7]. Two absorption bands, which are 45 cm^{-1} apart, are observed in the spectra of these alcohols with diaxially oriented OH and furyl groups. The half width of the additional band is 38 cm^{-1} , while the half width of the band of a free hydroxy group is 16 cm^{-1} . The relative intensities of these bands do not change upon dilution of the solution but depend on the substituents in the molecules and the solvent. Thus the intensity of the additional band increases sharply in the spectrum of N-methyl derivative VI. As compared with CCl_4 , chloroform stabilizes the form responsible for the low-frequency absorption. On the basis of these data it was assumed that the additional band arises as a result of the formation of an intramolecular hydrogen bond between the OH group and the ether oxygen atom of the furyl group.

An explanation of the appearance of two or several bands in the ν_{OH} region in the spectra of dilute solutions of the alcohols is given in the literature. For example, the complex absorption in the spectrum of the β isomer of 1-benzyl-4-methyl-3-phenyl-3-piperidinol is ascribed to stretching vibrations of an OH group included in intramolecular interaction with the unshared pair of electrons of the nitrogen atom (broad band at 3480 cm^{-1}) and the π electrons of the phenyl ring (narrow band at 3600 cm^{-1}) [8]. The complex band, the half width of which does not exceed 30 cm^{-1} , in the spectra of axial and equatorial tertiary cyclohexanols [9, 10] is associated with the phenomenon of retarded rotation of the hydroxy group about the C-O bond. It was shown that the absorption depends on the presence of alkyl substituents in the α , β , and γ positions and their orientation. To determine the number of rotational isomers and their percentages the complex band was separated into components; it was assumed that the molar absorption coefficients were the same for the three possible rotamers. It was found that only two rotamers can exist in solutions of axial alcohols with an axial γ substituent.

Thus taking into account the possibility of retarded rotation of the OH group about the C-O bond and its participation in the formation of relatively weak intramolecular hydrogen bonds with the heteroatoms or π systems, one can understand the complex character of the absorption of the OH group in the IR spectra of alcohols III and IV and compounds that we have previously studied [7].

The two partially overlapped bands at 3616 cm^{-1} ($\Delta\nu_{\frac{1}{2}} = 16\text{ cm}^{-1}$) and 3588 cm^{-1} ($\Delta\nu_{\frac{1}{2}} = 28\text{ cm}^{-1}$) in the spectrum of III, in which the hydroxy and phenyl groups are axial, can be ascribed to the absorption of a free OH group and an associated OH group included in an intramolecular hydrogen bond with the π electrons of the phenyl ring. The simultaneous presence of two bands indicates that the energy of formation of this bond is insufficient for the realization in solution of one rotational isomer. Let us note that the half width of the absorption band of the associated hydroxy group is greater than the half width of the absorption band of the free hydroxy group and that its shift relative to the unassociated hydroxy group is 28 cm^{-1} .

The symmetrical band with one maximum at 3616 cm^{-1} ($\Delta\nu_{\frac{1}{2}} = 25\text{ cm}^{-1}$) in the spectrum of cis-fused alcohol IV with an axial OH group and an axial $\text{C}_{(9)}-\text{C}_{(8)}$ bond relative to the plane of the piperidine ring can be thought of as the superimposition of two closely located bands with $\Delta\nu_{\frac{1}{2}} = 16\text{ cm}^{-1}$. Their appearance is due to the absorption of an unassociated OH group in two nonequivalent rotamers. The nonequivalence arises as a result of the presence in the γ position of an axial $\text{C}_{(9)}-\text{C}_{(8)}$ bond of the carbocycle.

The two bands in the ν_{OH} region in the spectra of axial alcohols with an axial furyl substituent in the γ position can be ascribed to the existence in solution of two rotamers, one of which is stabilized by an intramolecular hydrogen bond of the OH...O type. In this case the shift of the low-frequency band and its half width are greater than for the OH group included in a bond of the OH... π type.

Consequently, certain rotamers of the three that are possible as a result of the action of intramolecular forces and the effect of the solvent are realized in each specific case. In ascertaining the reasons for the complex absorption in the ν_{OH} region it is desirable to bring in not only the frequencies of the stretching vibrations of the OH group but also the half widths of the bands, since intramolecular interactions of the hydrogen bond type lead to broadening of the bands.

EXPERIMENTAL

The PMR spectra were obtained with a Tesla BS-487C spectrometer (80 MHz). The assignment of the signals was made by means of spin decoupling. The IR spectra of dilute solutions of the alcohols (c $5 \cdot 10^{-3}$ – $1 \cdot 10^{-3}$ mole/liter) in CCl_4 were recorded with a UR-20 spectrometer in the ν_{OH} region.

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