Chemical Transformations of Ajmalicine: Structure and Stereochemistry of Some Interchangeable Transformation Products

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Received October 26, 1981

Several chemical transformations were carried out with ajmalicine (1), a heteroyohimbine alkaloid, with a view to studying the reactivity of the enolic ester system occurring in the heterocyclic ring. Ajmalicine hemiacetal (2) and ajmalicine 17-methyl acetal (6) were prepared by treating 1 with aqueous and methanolic sulfuric acid, respectively. C-17 epimerization of 6 was observed in polar aprotic solvents, but this isomerization in 2 was prevented due to hydrogen bonding between vicinal carbomethoxy and hydroxy groups. Ajmalicial (12), the aldehydic derivative of 1, was prepared by following a new one-step pathway. Both cyclic (12) and open (14) forms of ajmalicial, a hemiacetal, were isolated and characterized. The cyclic form (12) was found to exist in an all-chair conformation (11). But for the open form (14) the most stable conformation (15) demands that the D ring must ooccur in a twist-boat form. This spatial orientation facilitated an electrophilic attack by the C-16 aldehyde group at C-7. The product was shown to be a new isomer (16) of ajmalicial having a 5,16-secoajmaline skeleton. The preferred conformation of 16 is 17. This new isomer was susceptible to protic solvents. LAH reduction of 1 afforded ajmalicinol (23). The structures and conformations of all these products could be established from spectral analyses including ^{13}C NMR spectra.

Ajmalicine (1), the representative member of the heteroyohimbine group of indole alkaloids, bears an enolic ester system (ROHC=C—CO_2CH_3) as a part of its hetero E ring. The same system (R = H) is present in open form in demethylcorynantheine (10), the E-seco analogue of 1. The reactivity of this system in 10 was studied extensively and was used to construct the hetero E ring via mercuration and demercuration, leading to heteroyohimbanes and abeo-18-(17→16)-yohimbane.[1-3] Comparatively little attention had been paid to study the same for the corresponding cyclic form present in the heteroyohimbines. The classical approach of Wenkert et al.[4] to convert 1 into its E-seco derivative has recently been paralleled by another method followed by Siphar.[5] Transesterification[6] and preparation of derivatives with hydrazine[7] are other recent transformations of heteroyohimbines involving its hetero E ring. Herein we present several chemical transformations of the heteroyohimbine alkaloid with a view to studying the reactivity of the enolic ester system. Interesting products which may be considered as labile derivatives were isolated. These compounds had special steric features which could only be visualized and explained from molecular models.

The partial carbonium ion character of C-17 of 1 was exploited for preparation of ajmalicine hemiacetal (2) and ajmalicine 17-methyl acetal (6). Ajmalicial (12), the aldehydic derivative, was prepared following the reported procedure.[4] In the event considerable difficulties were encountered when Wenkert's experiments were tried to produce ring E-seco derivatives. We have also developed a one-step direct conversion of 1 into 12. These three derivatives, 2, 6, and 12, were either stereochemically or structurally labile. We could isolate either one (in case of 2 and 6) or both (in case of 12) of the interchangeable forms. It was possible to settle their structures and stereochemistry mainly on the basis of spectroscopic investigations, viz., UV, IR, ^1H NMR, ^{13}C NMR, and mass spectral data together with the consideration of relative thermodynamic stability and reasonable mechanistic arguments. LAH reduction of 1 was also performed, and this experimentation provided interesting results.

Results and Discussions

Ajmalicine Hemiacetal (2). Treatment of 1 with 5% sulfuric acid for 30 min under reflux conditions furnished yellow crystalline hemiacetal $C_{21}H_{26}N_2O_4$: mass spectrum, m/e 370.1771 (M^+); mp 167-168 °C dec; 40% yield (see Scheme I). The yield did not improve on prolonging the reaction. The parent peak (m/e 370) in the mass spectrum of 2 indicated the addition of a water molecule to 1 (M^+, m/e 352). Whereas an enolic ester system is characterized by an absorption near 250 nm in the UV region and by the appearance of a twin carbonyl absorption in the range 1700-1600 cm^{-1} in the IR region of spectrum, both these characteristics were absent in the spectra of 2. Instead, its IR spectrum displayed a band for saturated carbonyl at 1720 cm^{-1}, and the UV spectrum was typical of an indole derivative with a minimum at 248 nm. The structure 2, without any stereochemical assignment at C-16 and C-17, was assumed for this hemiacetal on the basis of foregoing discussions since the reaction conditions employed were not drastic enough so as to change the stereochemistry at C-3, C-15, C-19, and C-20. Furthermore, the initial nucleophilic attack should be at C-17. The 80-MHz ^1H NMR spectrum of 2 in $CDCl_3$ is in consonance with this structure, and from this spectrum the stereochemistry at C-16 and C-17 could be settled. Two possible conformers of 2 are 4 and 5. The latter corresponds to the structure 3. The C-17 proton appeared at δ 5.05 as a slightly diffused doublet (J = 6.8 Hz) which collapsed to

(1) Djakoure, L. A.; Jarreau, F.-X.; Goutarel, R. *Tetrahedron* **1975**, *31*, 2247.
(2) Djakoure, L. A.; Jarreau, F.-X.; Goutarel, R. *Tetrahedron* **1975**, *31*, 2695.
(3) Boivin, J.; Pais, M.; Goutarel, R. *Tetrahedron* **1977**, *33*, 305.
(4) Wenkert, E.; Wickberg, B.; Leight, C. L. *J. Am. Chem. Soc.* **1961**, *83*, 5037.
(5) Siphar, S. A. German Offen. 2630260, 1977; *Chem. Abstr.* **1977**, *86*, 171707.
(6) Omnium Chimique, S. A. French Demande. 2377405, 1978; *Chem. Abstr.* **1979**, *91*, 39719.
(7) Hannart, J. A.; Alphonse, J. German Offen. 2808262, 1977; *Chem. Abstr.* **1978**, *89*, 215644.

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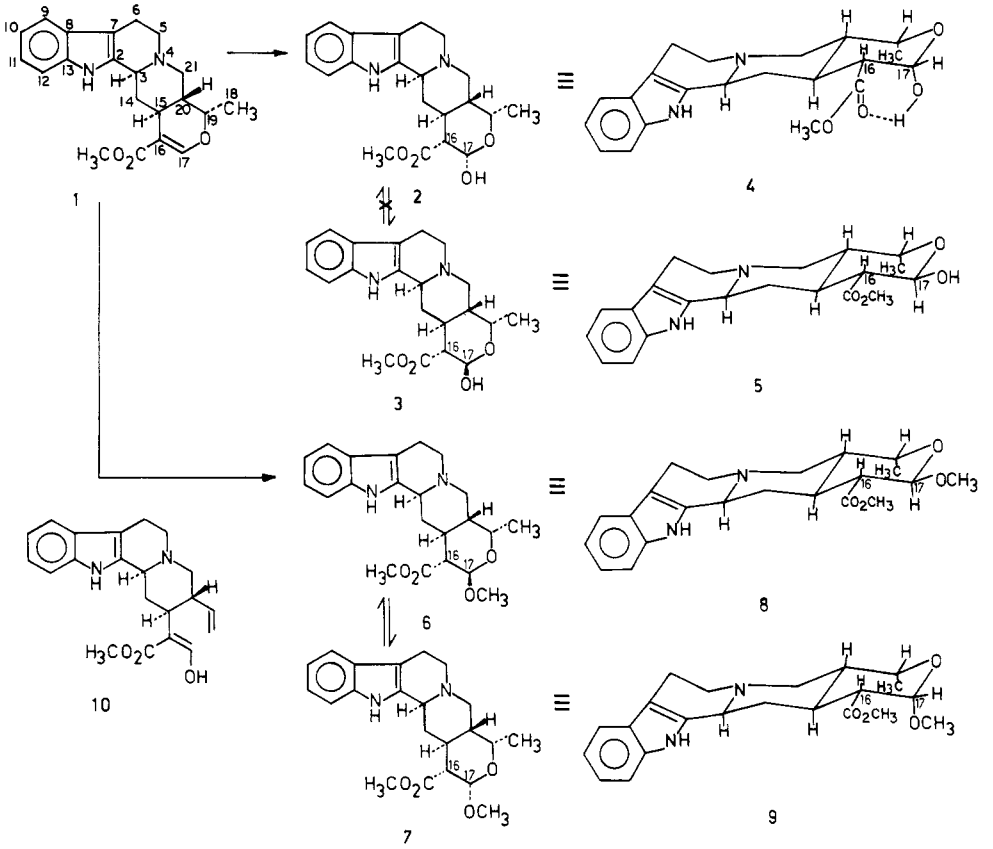
Scheme I



a singlet upon deuteration, showing the coupling constant between C-16 and C-17 protons to be nearly equal to zero. Since **2** was prepared under thermodynamically controlled conditions, the C-16 ester group must be α equatorial in **2**. The coupling constant value of ~0 Hz eliminated the *trans*-diaxial disposition of the two protons concerned. So the existence of the conformer **5** was not possible. The reported J_{cis} for such systems is 1 Hz.[3] A deviation from the standard J_{cis} value of 2–4 Hz in such systems can reasonably be accounted by the partial deformation of the heteroring caused by the oxygen atom. Further deviation from the 1 Hz value for **2** in all probability could be ascribed to increased deformation of this heteroring due to hydrogen bonding in **4**. As a result, the dihedral angle between the two protons is ~90°.

Now thermodynamically **5** should have been the more stable isomer because of lesser 1,3-diaxial interaction. Formation of the hydrogen bond must have overcome the instability of **2** owing to one axial substitution so that **4** could be obtained predominantly in this thermodynamically controlled reaction.

The existence of the hydrogen bonding was further emphasized when **4** did not undergo equilibration in polar aprotic solvents to furnish **5**. Here the hydrogen bonding must have prevented the usual facile isomerization of the hemiacetals. Instead, a part of it underwent dehydration to regenerate **1**, the observation being in accord with earlier findings.[8] In the ^1H NMR spectrum of **2** other protons appeared in the expected positions. Hemiacetals of enolic esters usually dehydrate quite easily[8] if there is any potential carbanion center from which the proton can readily participate in the elimination of hydroxyl of the hemiacetal. **2** was no exception as in its mass spectrum the relative intensity of the m/e 352 ($M^+ - 18$) peak increased steadily with respect to that of the parent m/e 370 peak with a rise in ignition temperature as depicted in Table I.

Table I. Variation of Molecular Peak Intensity of Ajmalicine Hemiacetal (2) with Ignition Temperature

temp, °C	% intensity with respect to the base peak of	
	m/e 370	m/e 352
<170	100	9
170	13	67
>170	9	71

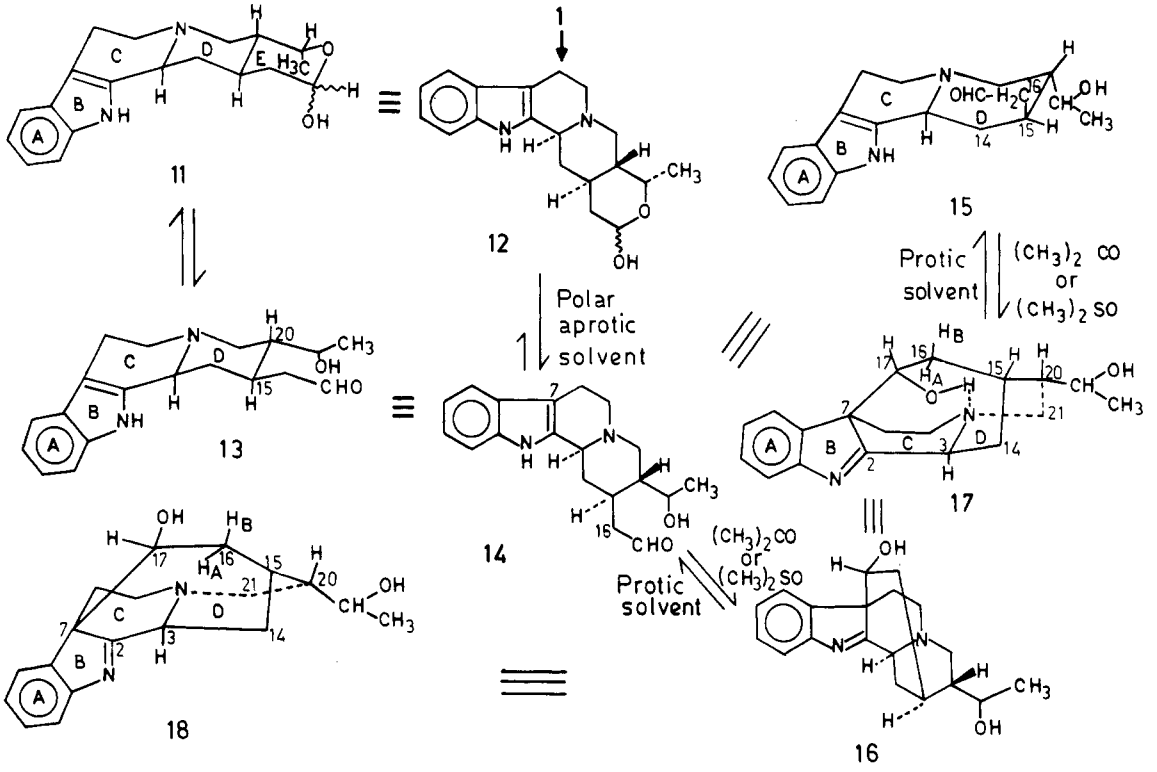
Ajmalicine 17-Methyl Acetal (6). Compound **1** afforded its 17-methyl acetal derivative when refluxed with 5% sulfuric acid in methanol. The pale yellow crystalline ajmalicine 17-methyl acetal [$C_{22}H_{28}N_2O_4$ (M^+, m/e 384.2037); mp 128–130 °C] was identified on the basis of its spectral characteristics. Both the UV and IR spectra clearly demonstrated the absence of the enolic ester system. Hence the addition of one molecule of methanol to **1**, as evident from the molecular ion peak, resulted in the formation of **6** or **7**. The stereochemistry at C-3, C-15, C-19, and C-20 should be the same as in **1**, and the C-16 proton must be β-axially oriented under the reaction conditions.

This structural assignment was confirmed and the stereochemistry at C-17 settled from a detailed study of the 80-MHz ^1H NMR spectrum of this acetal in $CDCl_3$. Two conformers corresponding to **6** and **7** are **8** and **9**, respectively, of which **8** is the most stable on thermodynamic grounds. The coupling constant values expected for C-17 proton in **8** and **9** are J_{aa} = 5–10 Hz for **8** and J_{ae} = 2–4 Hz for **9**.

For this compound the C-17 proton appeared as a doublet at δ 4.65 (J = 8 Hz), indicating **8** as the existing conformation at 30 °C.

(8) Fonzes, L.; Lucas, C.; Pavia, A.; Winternitz, F. *Phytochemistry* **1969**, *8*, 1797.

Scheme II



Compound 6 unlike **2** underwent equilibration when kept in a polar aprotic solvent like $CHCl_3$. The 80-MHz ^1H NMR spectrum of the equilibration mixture showed that **7** was present (30%). For **7** (the conformer **9**) the C-17 proton doublet at δ 4.85 had a coupling constant value of 2.7 Hz, confirming the cis disposition of the C-16 and C-17 protons. The carbomethoxy and methoxy signals for **9** were detected at δ 3.64 and 3.29, respectively. Other proton signals for **8** and **9** were almost identical with the remaining proton signals appearing at appropriate positions.

Ajmalicial (12). A new one-step procedure for preparing ajmalicial (**12**) from **1** was developed. The yield was 80%. The previous method for this conversion[4] consisted of several steps, and the yield was not satisfactory.

Compound **1** was refluxed with 3 N hydrochloric acid at 160 °C in a sealed tube for 2 h to furnish ajmalicial. This, being a hemiacetal, was expected to exist in both a cyclic (**12**) and the corresponding open-chain form (**14**, conformer**13**; see Scheme II).

The crystallization of ajmalicial from an almost nonpolar medium (petroleum ether–$CHCl_3$, 98:2) afforded a yellowish white amorphous solid: $C_{19}H_{24}N_2O_2$; mass spectrum, *m/e* 312 (M^+); mp 216–217 °C. But a concentrated solution in acetone furnished yellow granular crystals: $C_{19}H_{24}N_2O_2$; mass spectrum, *m/e* 312.1847 (M^+); mp 245 °C. The characteristic difference between these two crops, in spite of their isomeric nature, was established from their direct comparison (co-TLC, mixture melting point, and IR). The presence of an aldehyde carbonyl in the yellow crystalline crop (mp 245 °C) was reflected from its IR spectrum (absorption peak at 1710 cm^{-1}) whereas that of the amorphous form demonstrated no carbonyl absorption. TLC experiments showed the crystalline form to be the less polar and also the gradual conversion of the more polar amorphous form into the less polar one in polar aprotic solvents.

All the spectral data for the amorphous form including its ^1H NMR and ^{13}C NMR analyses are in excellent agreement with the structure **12** (conformer **11**) assigned to this acetal. So at first the other form was expected to have the structure **14**, having the all-trans conformation **13** similar to that of **11**. But representation **13** could not explain the ^1H NMR and ^{13}C NMR spectral signals observed for the crystalline form of ajmalicial. Moreover, on assumption of **13** as the conformation of crystalline ajmalicial, its enhanced stability over that of **11** in polar aprotic solvents could not be rationalized. The examination of the molecular model (conformer **13**) of **14** revealed the D ring to exist in the chair form with two bulky equatorial substituents at C-15 and C-20. Interaction between these two substituents would be less if they had a *trans*-diaxial disposition as in **15**. Flipping at the C-15 center of **13** converts the D ring of **14** from a chair to a twist-boat configuration (conformer **15**) in which the substituents are pseudodiaxial. In **15** the C-15 substitution suffered no 1,3-diaxial interaction whereas the C-20 pseudoaxial substituent suffered one weak 1,3-diaxial interaction with the C-14 axial proton. But the indole NH and C-16 aldehyde group in **15** were in close proximity, so as to form a hydrogen bond which could overcome the destabilizing effect of the weak 1,3-diaxial interaction. Thus conformer **15** could explain (i) the increased stability of **14** over **12** in polar aprotic solvents, which facilitated the hydrogen bond formation, and (ii) the lower intensity of the $M^+ - 18$ peak (*m/e* 294) in the mass spectrum of **14** compared to that for **12**. For conformation **13** the intensity of this peak should have been comparable to that of **12**.

Since the solubility of **15** in $CHCl_3$ was very poor, its 80-MHz ^1H NMR and ^{13}C NMR spectra were studied in Me_2SO-d_6. Moreover, these two spectra could not be accounted for on the basis of conformation **15** alone. A close inspection of a molecular model of **15** revealed the possibility of an electrophilic attack at C-7 by the aldehyde group to produce **16** of which two conformations are possible, viz., **17** and **18**. In **17** the C ring was in the boat form and the D ring in the half-chair form while **18** had its C ring in the half-chair form and the D ring in the boat

Table II. ^{13}C NMR Spectral Data[a] for Two Forms of Aimalicial

carbon no.	chemical shift, ppm (multiplicity) for 12 (conformer 11)	for 16 (conformer 17)
2	135.59 (s)	135.60 (s)
3	59.55 (d)	59.54 (d)
5	52.70 (t)	55.85 (t)
6	21.49 (t)	32.16 (t)
7	106.03 (s)	94.63 (s)
8	126.54 (s)	126.54 (s)
9	118.14 (d)	118.12 (d)
10	120.14 (d)	120.11 (d)
11	117.28 (d)	117.28 (d)
12	110.83 (d)	110.82 (d)
13	135.86 (s)	135.84 (s)
14	36.12 (t)	36.14 (t)
15	31.21 (d)	48.62 (d)
16	42.80 (t)	32.81 (t)
17	88.96 (d)	59.55 (d)
18	14.29 (q)	21.46 (q)
19	70.31 (d)	59.11 (d)
20	39.99 (d)	26.78 (d)
21	56.42 (t)	52.67 (t)

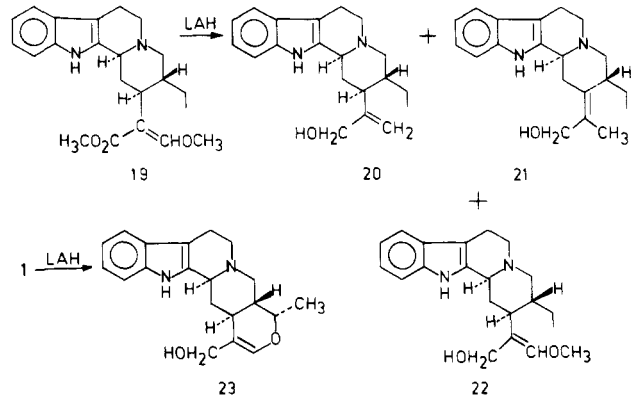
[a] $\delta(Me_4Si) = \delta(Me_2SO\text{-}d_6) + 39.5$ ppm.

form. The construction of the models of both the conformers at once revealed the greater steric strain inherent in 18. The ^1H NMR and ^{13}C NMR spectra for this compound (16) were in conformity with conformation 17.

The characteristic feature of the ^1H NMR spectrum of 17 was a sharp singlet at δ 1.55 flanked by two other small peaks, their height being about $^1/_6$th of the singlet. The C-16 methylene in 17 (not in 18) was found to be within the shielding zone of the aromatic nucleus, and from the model the dihedral angle of the C-16 H_A with both the C-15 and C-17 protons was found to be almost 90°. So the coupling constants for the C-16 H_A would be very small whereas C-16 H_B could couple with both the vicinal protons, their coupling constants being nearly the same. Thus, theoretically the C-16 methylene multiplet was expected to emerge as a three-line signal, the ratio of the peak heights being about 1:6:1. The spacing between the lines would be equal to the coupling constant value of either the C-17 or the C-15 proton with C-16 H_B. This type of multiplet was actually detected in this case at δ 1.55 (J = 6.1 Hz), and the C-19 methyl doublet at δ 1.17 (J = 5.0 Hz) partially merged with the upfield signal of this multiplet. The whole multiplet integrated for five protons. The C-19 proton resonated as a multiplet at δ 3.85 while the C-3 proton, deshielded by the indolenine double bond, resonated as a triplet at the comparatively downfield region of δ 4.4. The appearance of the multiplet at δ 1.55 indirectly fixed the conformation of C-17 in which the hydroxyl group should be directed away from the aromatic nucleus, when it was found to occupy the space just above the basic nitrogen atom. The distance between them was so small that the hydrogen bond formed between them must be very strong. This prevented the hydroxyl group from coupling with the C-17 proton. As a result it appeared as a singlet at δ 5.45. The four aromatic protons were detected in their normal position as a multiplet.

It was observed that when 14 was kept for a few hours in $Me_2SO\text{-}d_6$, the ^1H NMR spectrum displayed no band for CHO and NH groups. But addition of 2 drops of D_2O to the solution gave rise to two additional peaks at δ 10.75 and 10.7, respectively corresponding to CHO and NH. But in a fresh solution of 14 in $Me_2SO\text{-}d_6$ both the peaks were observed. This observation exhibited the instability of the C-7, C-17 linkage in protic solvents and probable equilibration of 15 with 17.

Scheme III



The ^{13}C NMR spectral data for 12 and 16 are tabulated in Table II.

The signals were assigned tentatively by comparison with the reported ^{13}C NMR data for alkaloids.[9] C-7 appeared as a singlet at 106.03 ppm in 12 and at 94.63 ppm in 16. Chemical shifts for other members of the A–C rings were nearly identical for these two isomers with the exception of C-6, which was rather deshielded in 16 primarily by the influence of an extra β effect of C-17, and C-5 was deshielded by partially positively charged N-4. C-15 was comparatively deshielded in 16 because of its closer proximity to the aromatic deshielding zone in 16 than in 12. But C-16 and C-17 were in the shielding zone of the aromatic group in 16 and were probably also shielded by internal steric interaction. C-19, C-20, and C-21 are somewhat more shielded in 16 than in 12 which could be attributed to the steric compression effect exerted by the rigid cagelike structure of 16.

Supportive evidence was indeed available from UV spectral study of these two isomers in different solvents. Both 12 and 14 showed UV absorption maxima in 95% ethanol at 226, 283, and 288 nm, i.e., typical of an indole moiety. But in $CHCl_3$ the maxima were shifted to 242, 270, 279 (sh), and 290 (sh) nm for both the isomers which was typical of an indolenine derivative (16) mixed with an indole. This mixture on being allowed to stand gave UV absorption maxima of purely indolenine derivatives when the shoulder peak at 279 nm disappeared. Both the isomers in acetone showed the same absorption maxima at 326 nm. This was explained by considering a possible partially zwitterionic form of the molecule formed by association of the C-17 hydroxyl proton with N-4 (17). The higher acidic character of allylic C-3 proton is due to this association. This resulted in the distribution of a partial positive charge enveloping C-3, N-4, and the C-17 hydroxyl group which is stabilized in acetone. This could taken as equivalent to an extended conjugation of the aromatic nucleus which shifted the maximum to a higher absorption value (326 nm). 12 was acetylated with $NaOAc/Ac_2O$ to furnish acetylajmalicial: $C_{21}H_{26}N_2O_3$; mass spectrum, m/e 354 (M^+); mp 58 °C. Since acetylajmalicial could not equilibrate, its UV spectrum in $CHCl_3$ demonstrated the presence of a simple indole moiety (240, 281, and 288 nm).

Ajmalicinol (23). LAH reduction of alkaloids bearing an enolic ester in an open form was known to cause other changes besides normal ester group reduction. Thus dihydrocorynantheine (19) upon LAH reduction underwent demethoxylation and double bond isomerization to furnish

(9) Shamma, M.; Hindenlang, David M. "Carbon-13 NMR Shift Assignments of Amines and Alkaloids"; Plenum Press: New York and London, 1979.

two isomeric desmethoxy dihydrocorynantheine alcohols (20 and 21, Scheme III) in addition to dihydrocorynantheine alcohol (22), the desired reduction product.[10]

We intended to study the behavior of 1, the cyclic analogue of 19, under similar conditions. But in this case nothing unusual, excepting normal ester group reduction, happened, producing ajmalicinol (23). Even prolonged (72 h) refluxing with LAH in THF caused no unusual change in 1.

Experimental Section

General Methods. Melting points were recorded in a Kofler block and are uncorrected. Preparative TLC was done with silica gel (Gouri Chemicals, Calcutta). The UV spectra were recorded in a Varian 634 spectrophotometer, IR spectra in a Beckman IR-20 spectrometer, and 80-MHz ^{1}H NMR and ^{13}C NMR spectra in a Varian CFT-20 spectrometer, Me_4Si being used as an internal standard. All reactions were carried out under a completely dry, oxygen-free nitrogen blanket.

Preparation of Ajmalicine Hemiacetal (2). Ajmalicine 1, (100 mg) was refluxed with 15 mL of 5% sulfuric acid. From the reaction mixture was separated 2 by prparative TLC, and it was crystallized from a benzene–ethyl acetate mixture: 40 mg; UV (EtOH) 226, 283, 289 nm; IR (KBr) ν_{NH} 3380 cm^{-1}; $_1$H NMR ($CDCl_3$) δ 7.6 (s, NH), 7.4–6.8 (m, aromatic protons), 5.05 (d, C-17 H), 4.15 (m, C-19 H), 3.75 (s, ester methyl), 1.23 (d, J = 6 Hz, C-19 methyl).

Preparation of Ajmalicine Acetal (6). Compound 1 (100 mg) was refluxed with 5% methanolic sulfuric acid for 45 min. 6 was isolated by preparative TLC and purified by crystallization from a benzene–methylene ch loride mixture: 35 mg; UV (EtOH) 225, 282, 290 nm, maximum at 249 nm; IR (KBr) ν_{NH} 3400, ν_{CO} 1735 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 7.95 (s, NH), 7.5–7.0 (m, aromatic), 4.65 (d, C-17 H), 4.13 (m, C-19 H), 3.71 (s, ester methyl), 3.34 (s, methoxyl), 1.12 (d, J = 6 Hz, C-19 methyl).

Preparation of Ajmalicial (12 and 14). Compound 1 (100 mg) was refluxed with 3 N hydrochloric acid at 160 °C for 2 h. Ajmalicial was the sole product, and it was purified by crystallization. For 12: IR (KBr) $\nu_{NH/OH}$ 3280 cm^{-1}; ^{1}H NMR (Me_2SO-d_6) δ 10.64 (s, NH), 7.3–6.8 (m, aromatic), 6.02 (d, J = 6.5 Hz, C-17 hydroxyl), 4.86 (t, C-17 H), 4.0 (m, C-19 H), 1.12 (d, J = 6.2 Hz, C-19 methyl). For 14: IR (KBr) $\nu_{NH/OH}$ 3390 cm^{-1}.

Preparation of Ajmalicinol (23). To an ice-cold solution of 1.0 g of LAH in 50 mL of dry ether was added a solution of 100 mg of 1 in 75 mL of dry ether slowly and with stirring, which was continued for 24 h at 28–30 °C. Excess LAH was the decomposed with ice chips, and the organic portion was extracted from the mixture with ether. The combined ethereal layer was washed, dried and concentrated to afford a gummy solid. Crystallization from a benzene–chloroform mixture (4:1) furnished 60 mg of light yellow granular 23: $C_{20}H_{24}N_2O_2$; mass spectrum, m/e 324.1860 (M^+); mp 236–238 °C; UV (EtOH) 226, 283, 290 nm; IR (KBr) ν_{OH} 3520, ν_{NH} 3360, $\nu_{C=C}$ 1655 cm^{-1}; ^{1}H NMR (acetone-d_6) δ 7.4–6.5 (aromatic), 6.17 (s, C-17 H), 4.15 (m, C-19 H), 1.05 (d, J = 6.5 Hz, C-19 CH_3).

Acknowledgment. Sincere thanks are accorded to Mr. Somnath Ghosh and Dr. A. Banerji of our department for helpful suggestions and to Mr. D. J. Roy for helping in the experimental work. We are also thankful to Dr. B. C. Das (Institut de Chimie des Substances Naturelles, France), Professor F. Bohlmann (Institut für Organisch Chemie der Technischen Universität, West Berlin), and Professor M. Hesse (Organisch-Chemisches Institute, University of Zürich, Zürich) for mass spectral analyses. Finally, financial assistance from CSIR (India) to S.B. is gratefully acknowledged.

Registry No. 1, 483-04-5; 2, 81737-76-0; 6, 63569-19-7; 7, 63569-20-0; 12, 81737-77-1; 12 acetyl, 81671-29-6; 14, 81671-27-4; 16, 81671-28-5; 23, 60490-96-2.

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Laser-Induced Cycloadditions: The Carvone Photoisomerization†

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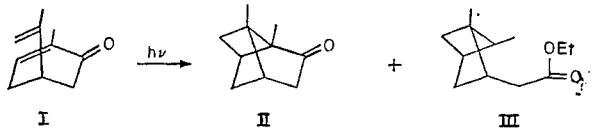
Received August 18, 1981

Laser flash photolysis of carvone yields triplet carvone. The lifetime is 75 ns in ethanol and 47 ns in cyclohexane. The photoisomerization reaction induced by UV pulsed lasers in the 350-nm range (XeF, 350 nm; YAG (third harmonic), 353 nm) gives carvone-camphor and trace amounts of 1-*exo*,5-dimethyl-*syn*-2-[(ethoxycarbonyl)-methyl]bicyclo[2.1.1]hexane. Photolysis with a CW laser, in the same wavelength region (Kr ion, 350.7- and 356.5-nm lines), results in a different product distribution. The differences are explained tentatively in terms of multiphotonic UV photolysis.

Introduction

The intramolecular photocycloaddition of carvone (I) to give carvone-camphor (II) was among the very first photochemical reactions studied and through the years the yield of II has been improved considerably from about 9% to 35%, by a careful choice of experimental conditions.[1-4]



I II III

Recently Zandomenghi[5] et al. investigated the photolysis using a Kr ion laser (350.7- and 356.5-nm lines) and reported a photoisomerization yield of about 88%. This was reported also to minimize the ring opening of II to the corresponding 1-*exo*,5-dimethyl-*syn*-2-[(ethoxycarbonyl)-methyl]bicyclo[2.1.1]hexane (III) and the concomitant

† Issued as NRCC 20357.

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