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NMR SPECTROSCOPY AND X-RAY CRYSTALLOGRAPHY OF BENZO[*a*]QUINOLIZIDINES[1]

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Abstract- A series of 9,10-dimethoxy-1,3,4,6,7,11b-hexahydro-2*H*-benzo[*a*]quinolizines **1**-**10** has been studied by nmr spectroscopy using two-dimensional techniques. The crystal structure of benzo[*a*]quinolizidines **1** and **4** has been determined by X-ray analysis.

In a previous work[1] we have described a new synthetic entry to the benzo[*a*]quinolizidin-2-one ring system prepared by the cyclization of 2-(3,4-dimethoxyphenyl)-4,4-ethylenedioxy-1-piperidineacetaldehydes followed by reduction of the resulting 7-hydroxy derivatives and hydrolysis of the acetal function. Benzo[*a*]quinolizidin-2-one **2** is a well known synthetic intermediate[2] of Ipecac alkaloids, such as emetine. However, in spite of the numerous studies about the synthesis and reactivity of benzo[*a*]quinolizidines,[3,4] a few studies of this ring system by ^{1}H nmr have been reported so far.[5] This technique has been usually used to assign the C-11b methine proton since its chemical shift value and its coupling constants allow the determination of the B/C ring junction.[6]

In this paper we report the study of the proton nmr spectra of benzo[*a*]quinolizidines **1**-**10**[1] by two-dimensional nmr spectroscopy of homo- (^{1}H-^{1}H) and heteronuclear (^{13}C-^{1}H) correlation[7] as well as by selective decoupling experiments.

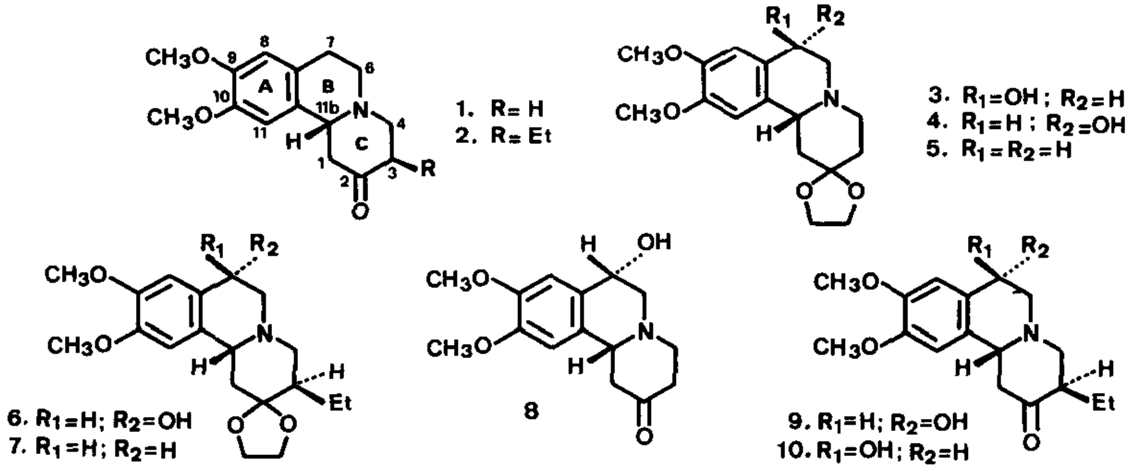


Figure 1

The most significant signals of 7-hydroxyquinolizidines 3, 4, and 6 are those due to the methine protons at C-11b and C-7. Thus, 11b-H appears at δ∿3.3 in the α-hydroxy series and at δ∿3.6 in the β-hydroxy series, in both cases as a doublet of doublets ($J \simeq 12$ and 2.5 Hz) which confirms both its axial disposition and the *trans* relationship of rings B and C.[5] The relative stereochemistry at C-7 in these compounds was established from the magnitude of the coupling constants of the 7-methine proton.[8] In addition, the presence of a pseudoequatorial hydroxy group in 3 implies a *syn* relationship between 7-H and the nitrogen lone pair, which promotes a shift to a lower field (Δδ∿0.3 ppm).[9] The change of the relative configuration at C-7 also affects the chemical shift of the aromatic 8-H proton. Thus, when the hydroxy group is pseudoaxial, the chemical shift difference between 8-H and 11-H is ∿0.25 ppm, while when it is pseudoequatorial this difference increases to 0.46 ppm.

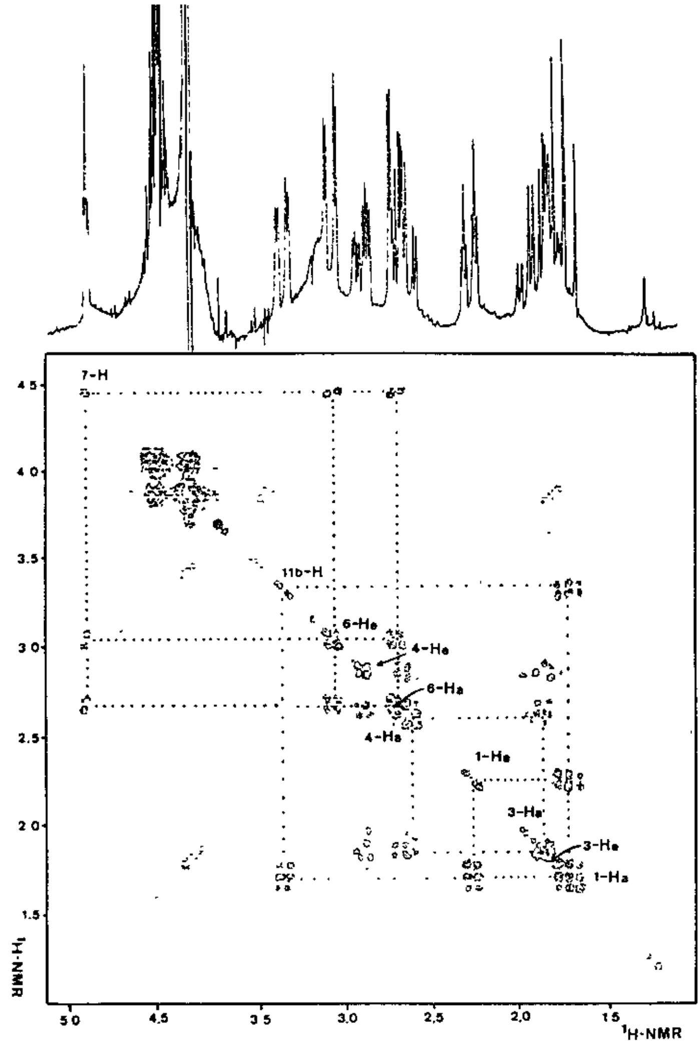


Figure 2. Two-dimensional Nmr Spectrum (COSY) of Compound 4

The deshielding promoted by the pseudoequatorial hydroxy group on 8-H is in agreement with the greater steric proximity of this proton and the oxygen lone pairs (see Dreiding models).[10,11] The remainder signals corresponding to the quinolizidine protons appear in the range of δ 1.5-3.2, showing in some cases an overlapping that makes difficult their unequivocal assignment. The complete signal assignment of quinolizidines **3**, **4**, and **6**[12] (Table 1) was accomplished from the 2D ^{1}H-^{1}H homocorrelated nmr spectrum of compound **4** (Figure 2). Selective proton decoupling experiments allowed the measurement of the coupling constants.

The *2D ^{1}H-^{1}H homocorrelated* nmr spectrum of **4** shows the following significant correlations: i) between the 7-H signal and the doublets of doublets at δ 2.69 and 3.05, which therefore correspond to the C-6 methylene protons. The signal at lower field is assigned to the proton *syn* with regard to the nitrogen lone pair;[9] ii) between the signal due to the methine 11b-H and the signals centered at δ 2.27 and 1.72, thus allowing their assignment to the equatorial and axial *C-1 protons, respectively*; iii) between the signal centered at δ 2.89, due to the equatorial 4-H proton, and the signals corresponding to 4-Ha and 3-H.

Reduction of hydroxy derivatives **4** and **6** led to benzo[*a*]quinolizidines **5** and **7**, respectively.[1] In both cases, the absence of the hydroxy group promotes the disappearance of the deshielding effect on 8-H. In fact, the aromatic protons resonate at δ 6.55 and 6.52 in **5** and at δ 6.59, as only one singlet, in **7**. The coupling constant of the methine 11b-H (J=12 Hz) confirms its axial disposition and the *trans* relationship between rings B and C.

In these compounds, the assignment of the quinolizidine protons is more difficult due to the greater overlapping of the signals corresponding to the methylene protons at C-6 and C-7 as a consequence of the absence of the deshielding promoted by the hydroxy group. The complete assignment (Table 1) was effected from the ^{1}H-^{1}H homonuclear correlation spectrum of compound **5** (Figure 3). The correlations between the broad doublet at δ 3.34, assigned to 11b-H, and the signals at δ 1.69 and 2.18 make evident the assignment of the latter to 1-Ha and 1-He, respectively. The greater deshielding of 1-He is due to the anisotropic effect exerted by the aromatic ring. In the same manner, 11b-H shows homobenzylic long distance correlation with the methylene protons at C-7,[13] thus allowing the assignment of the pseudoaxial 7-H at δ 2.98, *cis respect to the nitrogen lone pair, and the pseudoequatorial* 7-H at δ 2.62. Furthermore, correlations between the signal centered at δ 2.88, assigned to 4-He, and the signals at δ 2.50, 1.88, and 1.68 (4-Ha, 3-Ha, and 3-He, respectively), are observed. Finally, the signals of the methylene protons at C-6 have been assigned on the basis of their mutual correlation and their cross peaks with protons at the 7-position.

The interpretation of the nmr spectra of ketones **8**, **9**, and **10** was accomplished taking into account the deshielding effect (Δδ∿0.7 ppm) exerted by the carbonyl group on the vicinal protons.[14]

Finally, the deprotection of acetals **5** and **7** under acidic conditions led to benzo[*a*]quinolizidin-2-ones **1** and **2**, respectively.[1] The most significant signals in their ^{1}H nmr spectra were two singlets corresponding to the aromatic protons, two singlets due to the methoxy groups, and a doublet of doublets at δ 3.5 (J= 11-12 Hz) attributable to the axial C-11b methine proton.[15] In addition, characteristic signals due to the equatorial ethyl chain are observed in the spectrum of 2. For compound 1 the remaining signals are included in the range of δ 2.4-3.3 and their complete assignment was effected by means of the homo- (^{1}H-^{1}H) and heteronuclear (^{13}C-^{1}H) correlation spectra and by decoupling experiments. Thus, when the signal at δ 3.52 (11b-H) was irradiated, the signal centered at δ 2.47 became a broad doublet and therefore could be assigned to 1-Ha. This fits with the observed correlations between the signal of 11b-H and those due to the methylene protons at C-1. A long distance correlation between 11b-H and the methylene protons at C-7 was also observed (Figure 4). In the same manner, the homocorrelated spectrum allows the unequivocal assignment of the aromatic protons at position 11 and 8, at δ 6.66 and

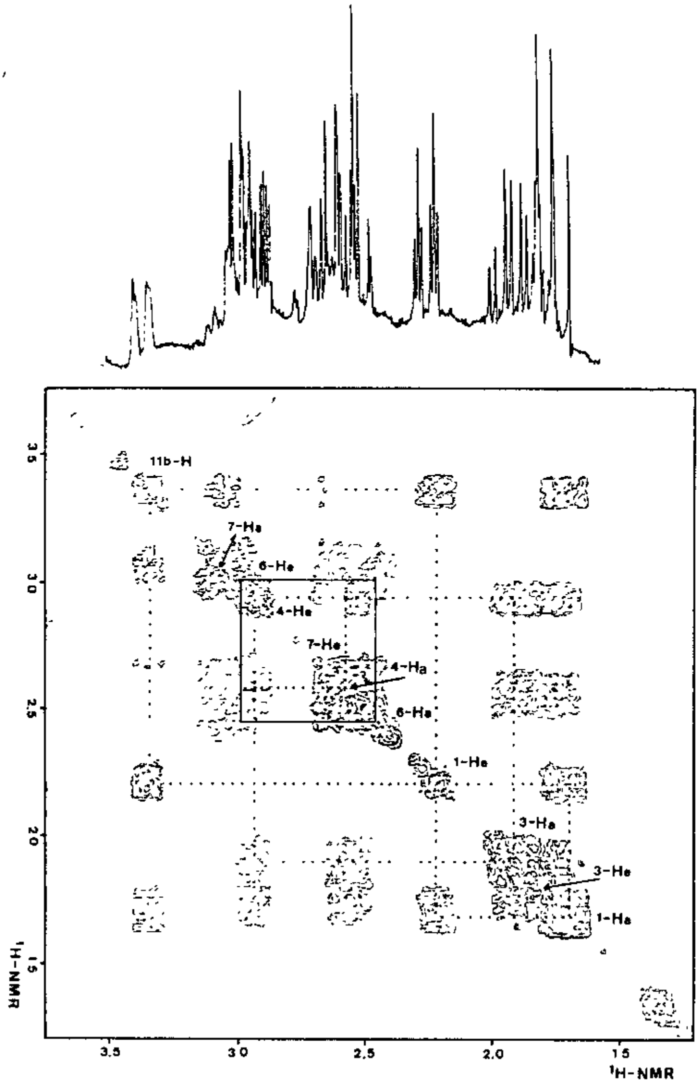


Figure 3. Two-dimensional Nmr Spectrum (COSY) of Compound 5

Table 1. ^{1}H Nmr^{a,b} Data of Benzo[*a*]quinolizidines 1-10

Proton	1	2	3	4	5	6	7	8	9	10
1-Ha	2.47 ddd (14, 12, 1)	2.50 dd (13, 11.5)	1.74 t (13)	1.72 t (12)	1.69 t (12)	1.58 t (12.7)	1.63 t (12)	2.46 dd (13, 12)	2.44 t^{c} (12)	2.62 t^{c} (11.5)
1-He	2.91 ddd (14, 3, 2)	2.88 dd (13, 3)	2.06 dt (13, 2.8)	2.27 dt (12, 2.4)	2.18 dt (12, 2.5)	2.28 dd (12.7, 2.5)	2.26 dd (12, 2.6)	2.96 dt (13, 2.2)	2.94 dd (12, 3)	2.5-2.8^{d}
3-Ha	2.65-2.75 m^{d}	2.6-2.8 m^{d}	1.90 td (13, 5.6)	1.90 td (12, 5)	1.88 td (12, 5)	1.82 m	1.9 m	2.5-2.7 m	2.55 m	2.4-2.7 m
3-He	2.42 ddd (11, 4.7, 2)	----	1.65 dq (13, 2.8)	1.77 m	1.68 dq (12, 2.5)	----	----	2.48 dq (12, 2.2)	----	----
4-Ha	2.65-2.75 m	2.38 t (10.7)	2.82 td (13, 2.8)	2.65 td (12, 3.6)	2.50 m	2.36 t (11.4)	2.30 t (12)	2.5-2.8 m	2.48 t^{c} (12)	2.68 t^{c} (11.5)
4-He	3.27 dd (10, 4.7)	3.32 dd (10.7, 6)	2.86 ddd (13, 5.6, 2.8)	2.89 ddd (12, 5, 2.4)	2.88 ddd (12, 5, 2.5)	2.96 dd (11.4, 4.4)	2.9-3.1 m^{d}	3.36 dm (10)	3.26 dd (12, 6)	3.28 dd (11.5, 5.7)
6-Ha	2.55-2.65 m	2.6-2.8 m	2.48 dd (11.2, 7)	2.69 dd (12, 2.4)	2.44 m	2.68 dd (12, 1.9)	2.45-2.75 m	2.74 dd (12, 2.2)	2.74 dd (11.7,2.2)	2.73 dd (11.5, 5.7)
6-He	3.0-3.2 m	3.0-3.2 m	3.22 dd (11.2, 4.2)	3.05 dd (12, 2.4)	2.92 m	3.06 dd (12, 2.5)	2.96-3.15 m	3.16 dd (12, 2.2)	3.18 dd (11.7,2.2)	3.40 dd (11.5, 3.5)
7-Ha	3.0-3.2 m	3.0-3.2 m	4.74 dd (7, 4.2)	----	2.98 m	----	2.96-3.15 m	----	----	4.75 br s (W1/2= 8)
7-He	2.7-2.8 m	2.6-2.8 m	----	4.46 t (2.4)	2.62 m	4.44 br s^{e}	2.45-2.75 m	4.54 t (2.2)	4.56 t (2.2)	----
8-H 11-H	6.58 s 6.66 s	6.56 s 6.63 s	6.99 s 6.53 s	6.87 s 6.62 s	6.55 s^{c} 6.52 s^{c}	6.87 s 6.60 s	6.59 s 6.59 s	6.92 s 6.57 s	6.92 s 6.58 s	6.99 s 6.50 s
11b-H	3.52 br d (12)	3.50 dd (11.5, 3)	3.58 dd (13, 2.8)	3.34 dd (12, 2.4)	3.34 br d (12)	3.30 dd^{f} (12.7, 2.5)	3.36 br d (12)	3.45 dd (12, 2.2)	3.42 dd (12, 3)	3.78 dd (11.5, 4)
OCH_3	3.83 s 3.86 s	3.83 s 3.86 s	3.84 s 3.87 s	3.86 s 3.88 s	3.77 s	3.87 s 3.88 s	3.84 s 3.86 s	3.90 s 3.85 s	3.87 s 3.91 s	3.85 s 3.89 s
CH_2CH_3	----	1.90 m 1.27 m 0.96 t (7)	----	----	----	1.6-1.7 m 1.0-1.3 m 0.94 t (7)	1.6-1.7 m 1.0-1.3 m 0.94 t (7)	----	1.85 m 1.30 m 0.98 t (7)	1.88 m 1.22 m 0.96 t (7)
OCH_2	----	----	3.9-4.1 m	4.0-4.1	3.9-4.0 m	3.9-4.1 m	3.8-4.1 m	----	----	----

[a] In ppm relative to TMS. Measured in $CDCl_3$ solution at 200 MHz. [b] Values in parentheses are coupling constants in Hz. [c] The assignment may be interchanged. [d] Masked. [e] Masked by OH signal. This signal appears at δ4.93 (J=2.6 Hz) in the hydrochloride. [f] Deshielded (δ4.42) in the hydrochloride.

6.58 respectively, on the basis of the correlation between the former and the axial proton at C-7 (δ 3.0-3.2) and of the latter and 11b-H. For the assignment of the signals corresponding to the protons at positions 3, 4, and 6, the study of the heteronuclear correlation spectrum was required (Figure 5). The ^{13}C nmr spectrum of compound 1 had been previously described.[6a] In a similar manner, the homonuclear correlation spectrum of benzo[*a*]quinolizidin-2-one 2 (Figure 6) allowed the complete assignment of the signals.

The X-ray crystal structures determined for benzo[*a*]quinolizidines 1 and 4 are illustrated in their three-dimensional representation (Figure 7). In compound 4, the structure consists of two molecules in the asymmetrical unit. The differences between the geometric values of two non-symmetrical equivalent molecules are less or equal to three times the standard deviations. Ring C has a chair conformation, with average ΔC_2^{3-4} and ΔC_m^3 symmetry parameters of 11.2 and 3.4°, respectively. The aromatic ring is planar (deviations from atoms to the mean plane are less than 0.023(7)°) with O(91), O(101), C(92), C(11b), and C(11a) atoms in the same plane.

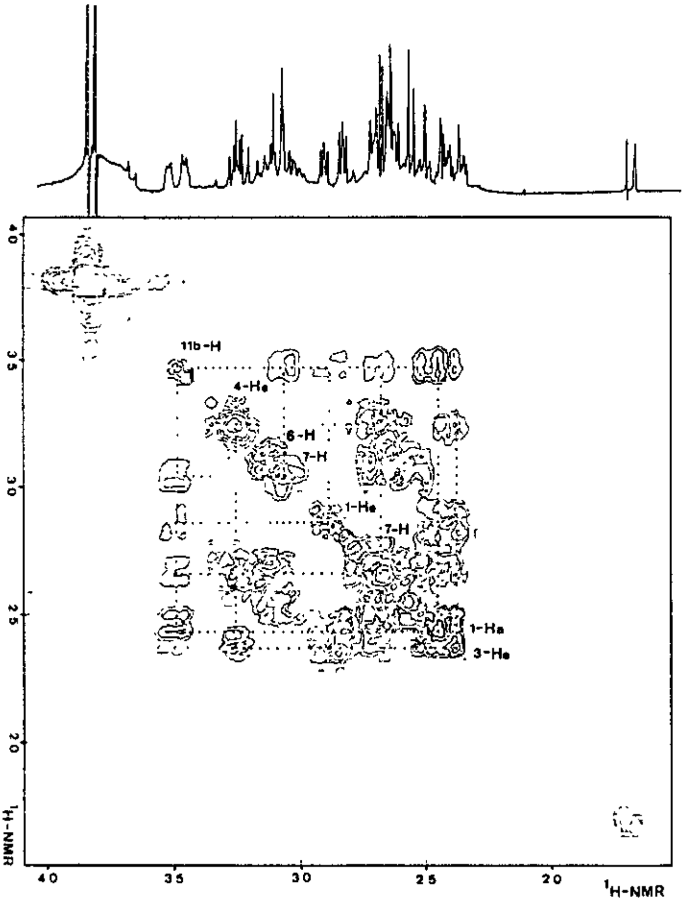


Figure 4. Two-dimensional Nmr Spectrum (COSY) of compound 1

The steric hindrance between the two methoxy substituents promotes the *syn* disposition of C(92) and C(102) atoms regarding C(8) and C(11) atoms, respectively. The C(8)-C(9)-O(91)-C(92) torsion angle is of 0.0(4)°, while the packing forces produce an average C(11)-C(10)-O(101)-C(102) torsion angle of 9.9(5)°. This conformation implies an enlargement of C(8)-C(9)-O(91) and C(11)-C(10)-O(101) bond angles to 126.0(1) and 124.9(8)°, respectively, as well as a narrowing of C(10)-C(9)-O(91) and C(9)-C(10)-O(101) bond angles to 115.4(1) and 114.3(5)°, respectively. The planarity of C(11b), C(11a), C(7a), and C(7) atoms in ring B gives to this ring a skew-chair conformation, with average ΔC_2^{5-6} and ΔC_m^{7} symmetry parameters of 12.9 and 48.3°, respectively. The five-membered ring has an envelope conformation with C(23) out of the plane defined by the remaining four atoms (average $\Delta C_m^{23}=2.3°$).

Finally, the structure of benzo[*a*]quinolizidin-2-one 1 consists of discrete molecules linked by van der Waals forces. The aromatic character of ring A produces that C(11b), C(11a), C(11), C(10), O(101), C(9), O(91), C(8), C(7a) and C(7) atoms are in a plane, with C(102) and C(92) atoms (-0.074(4) and -0.087(4) Å) out of this plane

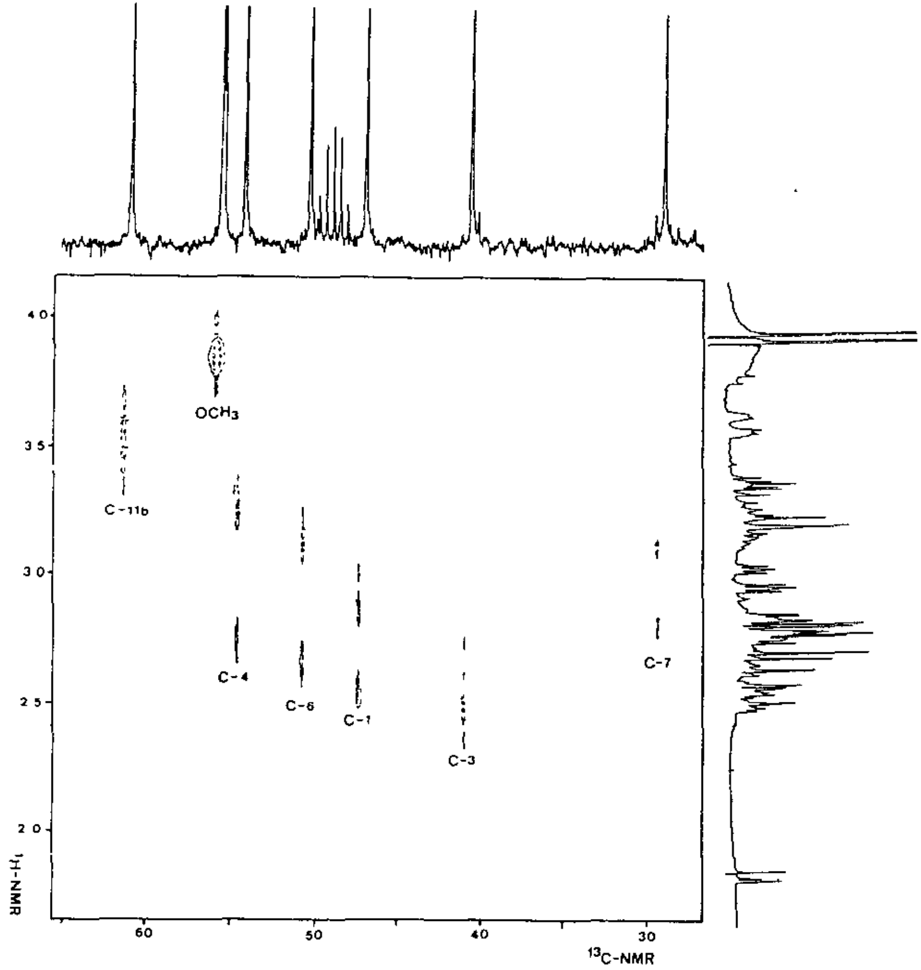


Figure 5. Two-dimensional Nmr Spectrum (HETCOR) of Compound 1

and at the same side. This fact and the π-donor character of N(5) promotes a shortening of C(7)-C(6) bond length to 1.513(6) Å (average length of the remaining C(sp^3)-C(sp^3) bonds: 1.539(1) Å). The C(11)-C(10)-O(101)-C(102) and C(8)-C(9)-O(91)-C(92) torsion angles are of 2.6(3) and -3.5(3)°, which produces an enlargement of C(11)-C(10)-O(101) and C(8)-C(9)-O(91) bond angles to 126.0(3) and 125.5(3)°, respectively. Ring B has a half-chair conformation, with ΔC_2^{5-6} =3.2°, whereas ring C has a chair conformation, with ΔC_s^5=1.1°, and presents N(5) and C(2) out of the plane defined by the remaining four atoms (0.718(5) and -0.470(5) Å, respectively). The remaining bond lengths have the typical values observed in the literature.[16]

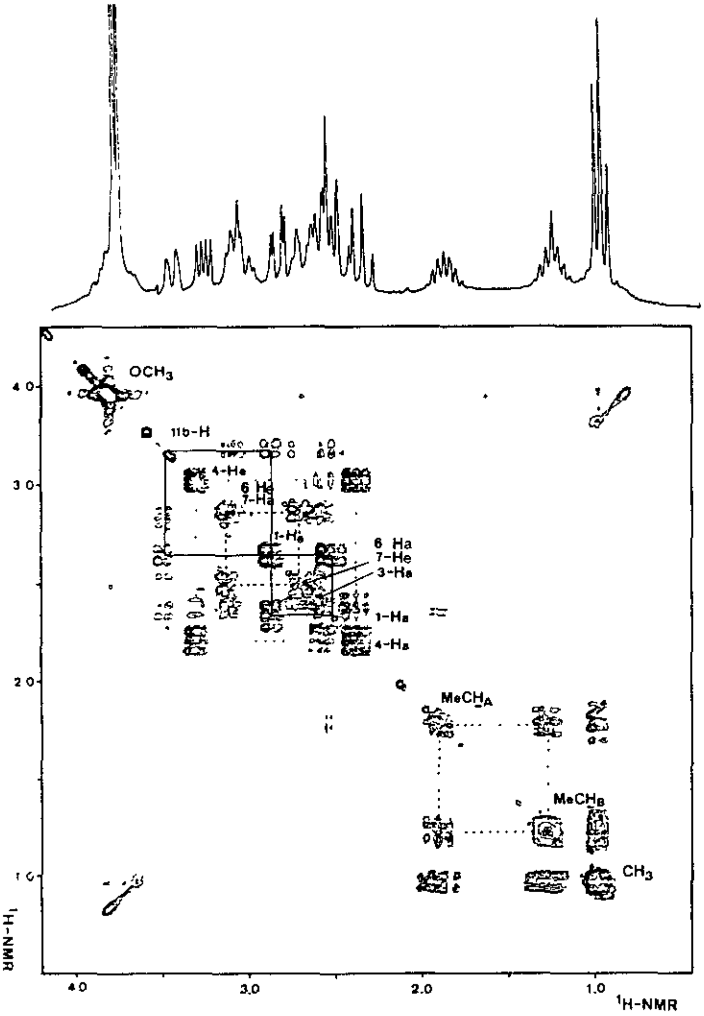
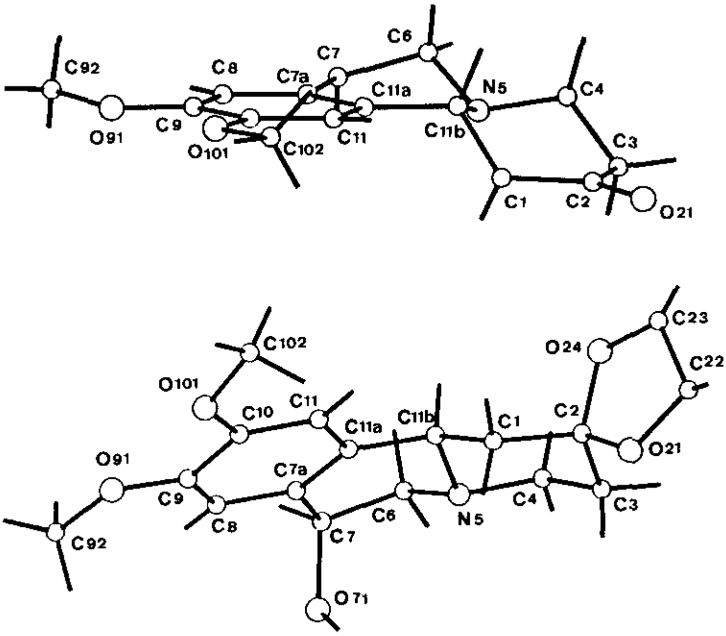


Figure 6. Two-dimensional Nmr Spectrum (COSY) of Compound $\underset{\sim}{2}$

EXPERIMENTAL

General. Nmr spectra were recorded on a Varian XL-200 spectrophotometer working at 200 MHz and 50.3 MHz, for proton and carbon, respectively. Chemical shifts are given in ppm. The ^{1}H-^{1}H homonuclear correlation experiments (COSY) were performed using the standard sequence,[17] and 32 transients were accumulated for 256 values of evolution



Compound 1

Compound 4

Figure 7. X-Ray Drawing of Benzo[*a*]quinolizidines 1 and 4

period, with a spectral width of 1600 Hz in both dimensions. The time between transients was 2 sec, and the acquisition time was of 0.160 sec. A 512x512 points data matrix was measured with pseudoecho[18] data for improved peak definition and triangular folding for improved sensitivity. The ^{13}C nmr and ^{1}H-^{13}C heteronuclear shift correlation experiments (the XCOR sequence written by D. L. Foxal, Varian, Palo Alto, was used) were recorded using a microcell (0.3 ml) and a high sensitivity ZENS probe. For the XCOR experiment 1760 transients were used for each one of the 64 values of the evolution period. The spectral width of ^{13}C nmr was 5500 Hz, with an acquisition time of 0.185 and a delay of 0.900 sec. The spectral width for ^{1}H nmr was 2000 Hz, 2048x512 data points were used.

Crystal data. Compound 1. $C_{15}H_{19}NO_3$. Fw=261.3, monoclinic, a=13.786(3), b=7.890(2), c=12.926(2) Å, β=104.91(2)°, V=1358.6(8) $Å^3$, $P2_1/n$, Dx=1.277 g cm^{-3}, Z=4, F(000)=560, λ(Mo Kα)=0.71069 Å, μ(Mo Kα)=0.96 cm^{-1}, 288 °K. Compound 4. $C_{17}H_{23}NO_5$. Fw=321.4, triclinic, a=18.190(3), b=14.082(3), c=6.974(2) Å, α=104.20(9), β=101.74(2), γ=102.78(2)°, V=1625(1) $Å^3$, P1 Dx=1.313 g cm^{-3}, Z=2, F(000)=688, λ(Mo Kα)=0.71069 Å, μ(Mo Kα)=1.04 cm^{-1}, 288 °K.

Crystallographic Measurements. A prismatic crystal (0.1x0.1x0.15 mm) was selected and mounted on a Philips PW-1100 four-circle diffractometer. Unit-cell parameters were determined from 25 reflections (4≤θ≤12°) and refined by least-squares. Intensities were collected with graphite monochromatized Mo Kα radiation, using the ω-scan technique, scan width 0.8°, scan speed 0.03° s^{-1}. 1560 Reflections were measured in the range 2≤θ≤24.5°, 1477 of which were assumed as observed applying the conditions I≥ 2.5 σ(I) for compound 1 and 3327 reflections in the range 2≤θ≤25°, 3147 assumed as observed in the same conditions for compound 4. Three reflections were measured every two hours as orientation and intensity control, significant intensity decay was not observed. Lorentz-polarization but no absorption corrections were made.

Table 2. Fractional atomic-coordinates ($x10^4$) for compounds 1 and 4.

	Compound 1				Compound 4		
Atom	x	y	z		x	y	z
C(1)	2760(3)	1723(5)	9067(3)	C(1)	1496(2)	2778(3)	-1341(6)
C(2)	2485(3)	1558(5)	10112(3)	C(2)	1051(2)	1915(3)	-3306(6)
O(21)	3106(2)	1284(5)	10939(2)	O(21)	951(2)	2306(2)	-5020(4)
C(3)	1393(3)	1787(6)	10080(6)	C(22)	1309(4)	1867(7)	-6427(9)
C(4)	695(3)	969(5)	9080(3)	C(23)	1531(4)	1034(5)	-5752(10)
N(5)	973(2)	1508(4)	8108(2)	O(24)	1512(2)	1232(2)	-3704(4)
C(6)	241(3)	957(6)	7146(3)	C(3)	253(3)	1371(3)	-3154(7)
C(7)	429(3)	1803(5)	6166(3)	C(4)	-190(3)	2127(3)	-2458(6)
C(7a)	1515(2)	1638(4)	6136(3)	N(5)	265(2)	2875(2)	-439(5)
C(8)	1788(3)	1865(5)	5185(3)	C(6)	-206(2)	3538(3)	285(6)
C(9)	2772(3)	1657(5)	5132(3)	C(7)	170(2)	4172(3)	2495(6)
O(91)	3119(2)	1847(4)	4235(2)	O(71)	-20(2)	3597(2)	3875(4)
C(92)	2385(4)	2206(8)	3255(3)	C(7a)	1046(2)	4597(3)	2900(6)
C(10)	3510(2)	1188(4)	6053(3)	C(8)	1468(3)	5321(3)	4801(6)
O(101)	4451(2)	986(3)	5919(2)	C(9)	2252(2)	5747(3)	5285(6)
C(102)	5210(3)	440(6)	6819(3)	O(91)	2706(2)	6454(2)	7097(4)
C(11)	3241(2)	969(4)	6997(3)	C(92)	2319(4)	6787(4)	8628(7)
C(11a)	2248(2)	1187(4)	7065(3)	C(10)	2654(2)	5469(3)	3804(6)
C(11b)	1993(2)	883(4)	8131(3)	O(101)	3441(2)	5959(2)	4397(5)
				C(102)	3864(3)	5836(5)	2893(10)
				C(11)	2263(2)	4750(3)	1915(6)
				C(11a)	1442(2)	4283(3)	1445(6)
				C(11b)	1006(2)	3486(3)	-611(6)

a. Crystallographic numbering scheme, as in Figure 7

Table 3. Bond lengths (Å) for compound 1 and 4 with e.s.d.s. in parentheses

Compound 1				Compound 4			
C(1)-C(2)	1.499(5)	C(8)-C(9)	1.385(5)	C(1)-C(2)	1.519(4)	C(7a)-C(11a)	1.400(6)
C(2)-C(3)	1.507(6)	C(9)-C(10)	1.401(5)	C(2)-C(3)	1.522(6)	C(8)-C(9)	1.355(6)
O(21)-C(2)	1.205(5)	O(91)-C(9)	1.372(4)	C(22)-O(21)	1.381(9)	C(9)-C(10)	1.410(6)
C(3)-C(4)	1.540(6)	C(92)-O(91)	1.431(5)	C(23)-C(21)	1.472(12)	O(91)-C(9)	1.365(4)
C(4)-N(5)	1.467(4)	C(10)-C(11)	1.375(4)	O(21)-C(2)	1.430(5)	C(92)-O(91)	1.436(7)
C(6)-N(5)	1.451(5)	O(101)-C(10)	1.362(4)	O(24)-C(2)	1.422(6)	C(10)-C(11)	1.382(4)
C(6)-C(7)	1.513(6)	C(102)-O(101)	1.416(4)	O(24)-C(23)	1.396(8)	O(101)-C(10)	1.371(4)
C(7)-C(7a)	1.513(5)	C(11)-C(11a)	1.404(4)	C(3)-C(4)	1.516(7)	C(102)-O(101)	1.421(8)
C(7a)-C(11a)	1.401(5)	C(11a)-C(11b)	1.526(4)	C(4)-N(5)	1.480(4)	C(11)-C(13)	1.426(5)
C(8)-C(7a)	1.387(5)	C(11b)-C(1)	1.538(5)	C(6)-N(5)	1.475(5)	C(11a)-C(11b)	1.516(4)
		C(11b)-N(5)	1.484(4)	C(6)-C(7)	1.505(5)	C(11b)-C(1)	1.542(6)
				C(7)-C(7a)	1.513(5)	C(11b)-N(5)	1.475(5)
				O(71)-C(7)	1.505(5)		
				C(7a)-C(8)	1.401(5)		

X-Ray Structure Analysis. The structure was solved by direct methods, using the MULTAN 84 system of computer programs[19] and refined by full-matrix least-squares method using the SHELX 76 computer program.[20] The function minimized was $\Sigma w/|Fo|-|Fc|/^2$, where $w=(\sigma^2(Fo)+0.023|Fo|^2)^{-1}$. All H atoms were obtained from a difference synthesis and refined with an overall isotropic temperature factor and anisotropically the remaining atoms. The final R factor was 0.059 (wR=0.070) for all observed reflections.

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11. The steric interaction between 8-H and a pseudoequatorial substituent at C-7 in benzo[*a*]quinolizidin-2-ones has been previously observed.[4f]

12. The assignment of nmr signals of compound **6** was corroborated from the nmr spectra of the hydrochloride: ^{1}H nmr (CD_3OD, 200 MHz) 1.01 (t, 3H, CCH_3), 1.2 (m, 1H, C*H*CH_3), 1.8 (m, 1H, C*H*CH_3), 2.0 (dd, *J*=13, 12 Hz, 1H, 1-Ha), 2.3 (m, 1H, 3-Ha), 2.74 (br d, *J*=13 Hz, 1H, 1-He), 3.16 (t, *J*=12 Hz, 1H, 4-Ha), 3.5-3.7 (m, 3H, 4-He and 6-H), 3.89 (s, 6H, OCH_3), 4.0-4.2 (m, 4H, OCH_2CH_2O), 4.42 (dd, *J*= 13, 3.2 Hz, 1H, 11b-H), 4.93 (t, *J*=2.6 Hz, 1H, 7-He), 6.79 (s, 1H, 11-H), 7.06 (s, 1H, 8-H); ^{13}C nmr ($CDCl_3$+CD_3OD) 9.5 (CH_2CH_3), 16.5 (CH_2CH_3), 36.3 (C-1), 41.4 (C-3), 54.1 and 54.5 (OCH_3), 55.9 (C-6), 59.9 (C-4), 62.0 (C-11b), 64.2 (OCH_2 and C-7), 105.1 (C-2 and C-11), 110.7 (C-8), 121.8 (C-7a), 124.7 (C-11a), 148.1 and 148.3 (C-9 and C-10).

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