Bis(1,2-dimethyl-3-indolizinyl)methane: Structural Studies of a Two-Bladed Molecular Propeller

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An X-ray structural investigation on bis(1,2-dimethyl-3-indolizinyl)methane (**1**) reveals that it occupies a two-bladed propeller conformation with an *anti*-relation between the central methylene protons and the four methyl groups. In the crystal, the molecule lacks a C_2 axis and it is asymmetric rather than helical. Since the two indolizinyl rings carry no substituents which can conjugate with their π systems the structural results supply, for the first time, accurate information about the geometry of the important heterocycle indolizine.

Bis(1,2-dimethyl-3-indolizinyl)methan: Struktur-Untersuchungen an einem molekularen Zweiblatt-Propeller

Eine Röntgenstrukturanalyse von Bis(1,2-dimethyl-3-indolizinyl)-methan (**1**) ergibt, daß die Verbindung eine Zweiblatt-Propeller-Konformation mit einer *anti*-Beziehung zwischen den zentralen Methylenprotonen und den vier Methylgruppen einnimmt. Im Kristall fehlt dem Molekül eine C_2-Achse, und es ist unsymmetrisch anstatt helical. Da die beiden Indolizinylringe keine Substituenten tragen, die mit ihren π-Systemen konjugiert sind, bieten die Struktur-Ergebnisse erstmals genaue Information über die Geometrie des bedeutenden Heterocyclus Indolizine.

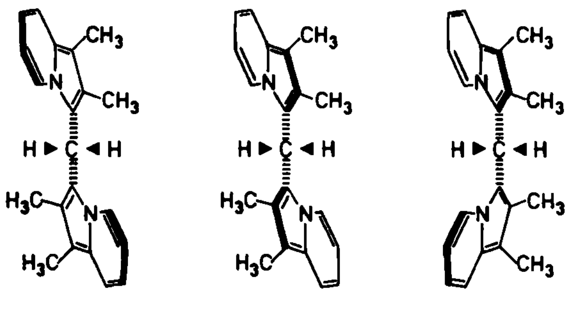
When bis(1,2-dimethyl-3-indolizinyl)methane (**1**) is dissolved in trifluoroacetic acid a $\approx 1:1$ mixture of two diastereoisomers is formed. One of them possesses C_2 symmetry and the other C_1. However, rotation of the two rings in the asymmetric stereoisomer leads to enantiomerization via a transition state having a plane of symmetry. The two 9-methylene protons, however, remain diastereotopic also in the transition state. The energy of activation for this process is apparently rather low and the molecule behaves like a *meso* form.

Bis(1,2-dimethyl-3-indolizinyl)methane (**1**), easily prepared from 1,2-dimethylindolizine and formaldehyde, was first described by Scholtz[1] and later investigated by Saxton[2] and by Reid et al.[3]. It belongs to the class of molecular propellers, whose configurational and dynamic properties have been studied in detail by Mislow et al.[4]. Although **1** has been known for a long time, relatively little has been reported about its properties. The present communication describes an X-ray-diffraction study of **1**, MNDO calculations on 1,2,3-trimethylindolizine (**2**), to correlate the experimentally determined bond-length values in **1** with theoretically calculated ones, and NMR studies on **1** and on the ions formed when it is protonated.

Discussion

X-ray investigations of diphenylmethane[5] and derivatives of it[6] have revealed that the majority of these compounds occupy a helical arrangement in the crystalline state. The title compound, **1**, analogous to a diarylmethane, is a two-bladed propeller with two identical rings lacking local C_2 axes. It can exist in either perpendicular or helical conformations, all chiral. Four perpendicular and six helical stereoisomeric conformations are possible[4]. The three possible helical conformations are represented in Scheme 1. In **1a** and **1b** the pairs of methyl groups are on opposite sides of a plane through C-3–C-9–C-3′, while in **1c** they are on the same side of this plane. In **1a** the methyl groups are *anti* to the C-9-methylene protons and in **1b** they are *syn*. In **1c** finally, one pair is *syn* and the other *anti* to the same protons. If the absolute values of the torsion angles for both rings are the same, **1a** and **1b** posses C_2, and **1c**, C_1 symmetry. They are interconvertible and racemized by a flipping-rotational process[4]. Measurements on Dreiding models predict **1a** to be least hindered stereoisomer.

Scheme 1. Helical conformations for one set of enantiomers of **1**



1a 1b 1c

Results

The molecular structure of **1** was determined by X-ray analysis. Crystallographic data are listed in the Experimental section. Like the diarylmethanes the crystals of **1** are monoclinic, space group $P2_1/c$. Interatomic distances and angles for the non-hydrogen atoms and for the hydrogens are indicated in Fig. 1. There is no statistically significant variation between the corresponding distances and bond angles in rings A and B.

A stereodrawing of **1** (Fig. 2) demonstrates very clearly that the molecule in the crystal exists as propeller with an

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anti relation between the two pairs of methyl groups and the C-9-methylene protons, in agreement with the predictions.

The molecule crystallizes in a centrosymmetric space group, that cannot accommodate molecules with only one chirality. Thus, of the four molecules in the unit cell two must have the same chirality and two the opposite.

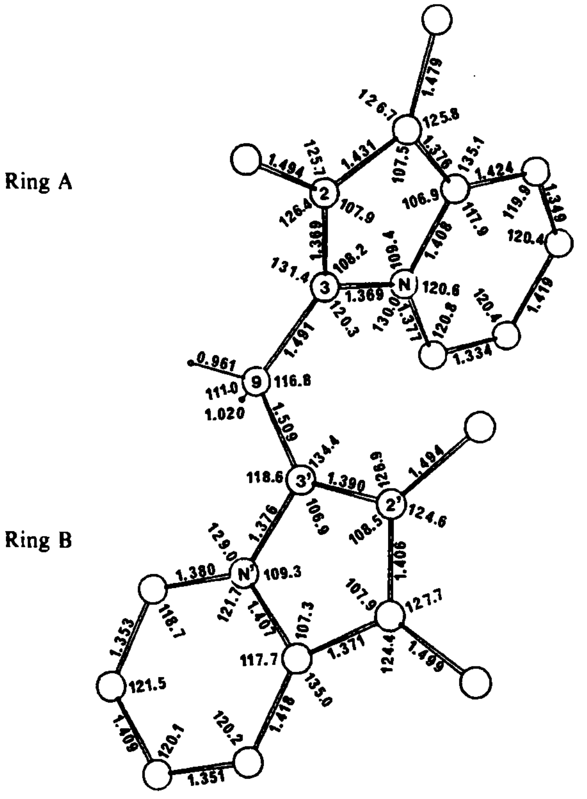


Fig. 1. Bond-length and bond-angle values in **1**. The standard deviations are 0.004–0.009 Å, respectively

The question whether the indolizinyl rings in **1** are planar or not is of fundamental interest. The X-ray results show, that the deviations from the least-square planes are in the range of 0.028 Å and that the two bridgehead N-atoms are ca. 0.014 Å outside the above-mentioned planes. Thus, the indolizinyl rings in **1**, and most likely also the parent molecule indolizine, are planar 10π systems. The central bond-angle value for C-3–C-9–C-3', 116.8°, is close to those reported for the diphenylmethanes carrying electron donating *ortho*-substituents[5]. The torsion angles for the planes of the two indolizinyl rings, related to the C-9–C-3 and C-9–C-3' bonds, respectively, are illustrated in Fig. 3 and summarized in Table 1.

Table 1. Selected torsion angles (°) in **1**

C3-C9 - C3'-C2'	11.0	C2-C3 - C9-C3'	-105.0
C3-C9 - C3'-N4'	-172.9	N4-C3 - C9-C3'	74.0
H9-C9 - C3'-N4'	-52.1	H9-C9 - C3-N4	-44.5
H9-C9 - C3'-N4	65.1	H9-C9 - C3-N4	-164.4
H9-C9 - C3'-C2'	131.7	H9-C9 - C3-C2	135.9
H9-C9 - C3'-C2'	-111.0	H9-C9 - C3-C2	16.1

From the two projections in Fig. 3 it is clear, that the molecule does not contain a crystallographic C_2-axis. The differences in torsion angles for the two planes are so large, that **1** is asymmetric rather than helical. Similar results have been reported for unsymmetrically substituted biphenyls and for symmetrically substituted biphenyls in which hydrogen bonding can occur[6]. The bond angles in the six-

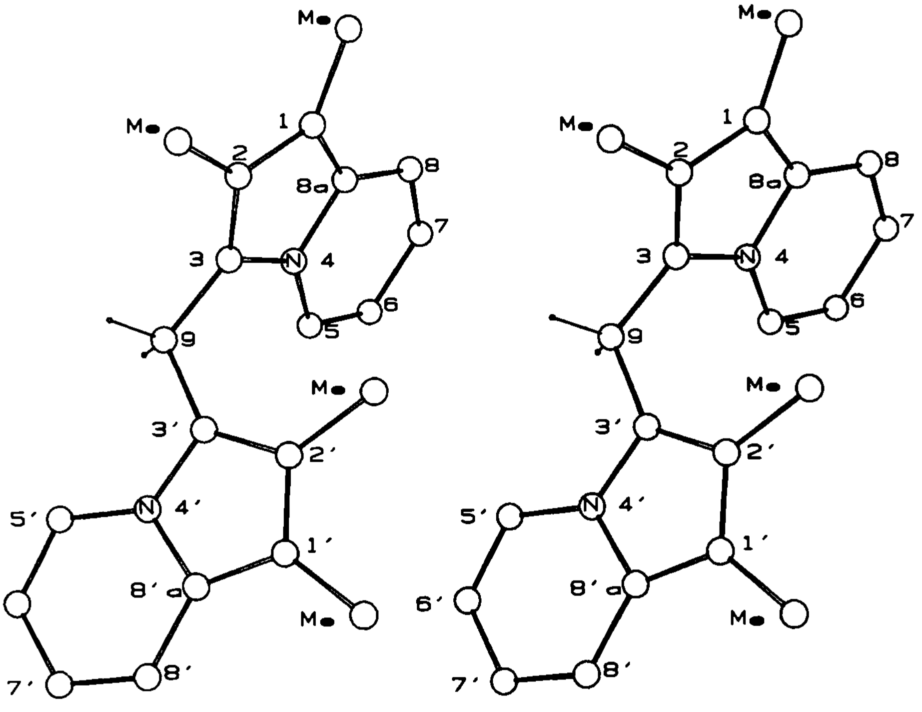


Fig. 2. Stereoview of the molecular structure of **1**

membered rings are all cluse to 120° and in the five-membered ca. 108°. One can observe a slight bond-length alternation in the six-membered rings and that the C-1 – C-2 bond seems to have single-bond character.

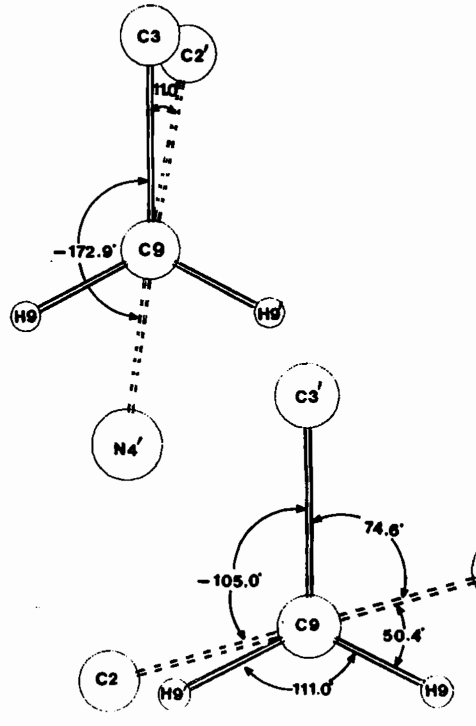


Fig. 3. Torsion angles for the two indolizinyl rings in **1** related to the C-9 – C-3 and C-9 – C-3′ bonds

Table 2. Interatomic distances in Å between selected C-atoms in **1**; SD: 0.004 – 0.007 Å

	1′-CH_3	2′-CH_3	C-5′
1-CH_3	3.825	5.200	3.967
2-CH_3	4.750	4.360	3.945
C-5	–	3.777	–

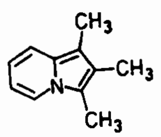
Interatomic distances between selected C-atoms in **1** have been calculated (Table 2).

The finding that corresponding distances between carbon atoms in the two rings, e.g. C-5 – 2′-CH_3 and C-5′ – 2-CH_3, which are the shortest, are different illustrates the absence of a C_2 axis in **1** and supports the conclusion that the molecule is asymmetric and not helical.

So far, only two X-ray structural studies on indolizines have appeared[7,8], both on compound with substituents that can conjugate with the π electrons in the ring.

In the first case, 1-(2-pyridyl)-3-benzoyl-6-bromoindolizine (**3**)[8], the pyridyl and carbonyl groups are 2 and 4°, respectively, out of the indolizine plane and consequently considerable conjugation exists with the 10π system. Also, the accuracy reported, $R = 0.13$, is rather low.

The second case, 1,1-bis(5-methyl-2-phenyl-1-benzoyl-3-indolizinyl)ethylene (**4**)[9], at first sight seems less than ideal. However, the X-ray, and also the UV data, show that the π systems of the substituents are all orthogonal to the plane of the indolizinyl rings and thus out of conjugation. These



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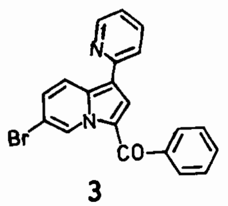

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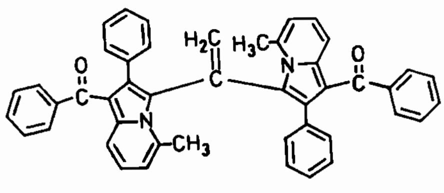

4

structural parameters, widely quoted in the literature, should therefore be useful for correlations.

The present study has been performed on an indolizine derivative carrying substituents, which do not enter into any conjugation; both NMR and UV data (vide infra) demonstrate that no interaction exists between the two rings in **1**. It is therefore reasonable to assume that the geometrical parameters of indolizine itself are very close to those of **1**.

A comparison of the bond lengths in the two rings of **1** (cf. Fig. 1) with the corresponding values reported by Oeser[9] for **4** (cf. Fig. 1 in ref.[9]) reveals that they are very close, although not identical.

In this context we wish to mention that we have subjected both indolizine and 1,2-dimethylindolizine to X-ray-diffraction studies, but without success. Indolizine is very volatile and unstable when radiated at temperatures above −10°C. Therefore, indolizine crystals, covered with an epoxy resin, were exposed to graphite monochromated Mo-K_α radiation at −130°C. The results, which will be reported elsewhere[10], show a structure with a six-membered ring over a five-membered, but disordered with respect to the position of the bridge-head nitrogen atom.

1,2-Dimethylindolizine, in which the position of the bridgehead nitrogen atoms is defined, is resonably stable and less volatile than indolizine. The only crystals we have been able to prepare consisted of thin flakes. In the reflexions, obtained at room temperature and at −100°C, the third dimension was completely absent.

MO Calculations

For a long time indolizine has been the subject of much theoretical interest and a considerable number of MO calculations and other theoretical studies have been reported for it[11]. Even so, we are aware of only two[12,13] which are concerned with bond-length values. Both are from 1973/1974 and both used an MNDO-2 program. At that time, experimental values for indolizine were not available. Therefore we have performed MNDO-SCF MO computations[14] on 1,2,3-trimethylindolizine (**2**), a molecule for which the number of atoms is within our computational resources, and which is also a good analogue for **1** and for indolizine. All parameters, bond lengths, bond angles, and dihedral angles, have been optimized.

The calculated values for **2** and the experimental values for the two rings in **1** and **4** are summarized in Table 3.

Table 3. The calculated bond-length values in 1,2,3-trimethylindolizine (**2**) and the experimental data for the two rings in **1** and in **4**, respectively, and in **3**

Bonds	in **2**[a]	in **1**[b]		in **4**[c]		in **3**[d]
		(Ring A)	(Ring B)	(Ring A)	(Ring B)	
C1-C2	1.443 Å	1.431 Å	1.406 Å	1.420 Å	1.426 Å	1.36 Å
C2-C3	1.411	1.369	1.390	1.393	1.384	1.45
C3-N4	1.409	1.369	1.376	1.397	1.407	1.44
N4-C5	1.406	1.377	1.380	1.385	1.382	1.41
C5-C6	1.373	1.334	1.353	1.373	1.365	1.32
C6-C7	1.442	1.419	1.409	1.402	1.411	1.51
C7-C8	1.371	1.349	1.351	1.348	1.367	1.53
C8-C8a	1.443	1.424	1.418	1.425	1.393	1.56
C8a-C1	1.409	1.376	1.371	1.369	1.375	1.53
C8a-N4	1.424	1.408	1.407	1.410	1.410	1.25

[a] Calculated by MNDO. — [b] Experimental values. — [c] From ref.[9]. — [d] From ref.[8].

The calculated values are consistently larger than the experimental by 0.016–0.042 Å. However, the results correctly predict the bond-length alternations in the six-membered ring and also the C-1–C-2 bond is longer than the other bonds in the five-membered ring. The poorest fit seems to be for the C-3–N-4 bond. The additional parameters calculated are the dipole moment (1.61 Debye), the heat of formation (29.0 kcal/mol), the ionization potential (7.96 eV), and the atomic charge densities (Table 4).

The charge densities have been calculated with a CNDO SCF-MO program[15], which used the geometry for the ring system obtained from the MNDO calculation. This approach was used since MNDO is parameterized against experimental data with no special weight on charge densities, while CNDO is parameterized against ab initio calculations and is known to perform better in this respect.

NMR Studies

Broad-band decoupled and completely undecoupled ^{13}C-spectra of **1** in $CDCl_3$ have been recorded. Chemical-shift and coupling-constant values are summarized in the Experimental section (Table 4). Our assignments are based on the values for indolizine and deuterated indolizine derivatives reported by Pugmire et al.[16]. Based on the data available we cannot, however, distinguish between the C-2/C-3 and C-7/C-8 signals in the spectrum of **1**.

Foote[17] and Mislow[18] have proposed correlations between ^{13}C-H spin-coupling constants and internuclear angles in alkanes. For systems with local C_{2v} symmetry, equation (1)

$$J = \frac{250(1+\cos\Theta_0)}{1-\cos\Theta_0} \quad (1)$$

has been deduced, where Θ_0 is the C–C–C interorbital angle calculated from the corresponding interatomic angle via equation (2).

$$\Theta_0 = 0.1340 \cdot \Theta_n + 94.84 \quad (2)$$

The experimental values determined in the present communication for the CH_2 group in **1a**, J = 125.9 Hz and Θ_n = 116.8°, correspond to the calculated values 115.0° and 120.4 Hz, respectively.

Table 4. ^{13}C-NMR chemical-shift values and C-H coupling constants for **1** and charge densities calculated for corresponding C-atoms in 1,2,3-trimethylindolizine (**2**)

Atoms	δ-values (ppm)	$^1J_{C-H}$-values (Hz)	$^3J_{C-H}$-values (Hz)	Charge densities
C-1	106.54 (s)	-	-	4.06
C-2	114.61 (s)	-	-	4.00
C-3	121.59 (s)	-	-	3.99
N-4	-	-	-	4.01
C-5	121.28 (d)	178.4	5.6 (C5-H7)	3.93
C-6	109.12 (d)	164.2	8.3 (C6-H8)	4.03
C-7	113.89 (d)	164.0	7.1 (C7-H5)	3.99
C-8	116.48 (d)	160.7	7.2 (C8-H6)	4.02
C-8a	129.19 (s)	-	-	3.93
9-CH_2	20.82 (t)	125.9	-	-
1-CH_3	8.65 (q)	125.8	-	3.99
2-CH_3	9.37 (q)	125.9	-	4.00
3-CH_3	-	-	-	4.01

The ^1H-NMR spectra of **1** in $CDCl_3$ and in [D_4]-*o*-dichlorobenzene from room temperature up to ≈100°C display only four two-proton signals for the ring protons, two doublets at 7.1 and 7.3 ppm (H5 and H8, respectively) with J-values of 5.2 Hz, and two triplets at 6.1 and 6.3 ppm (H6 and H7, respectively) with the same coupling constants. Two methyl resonances, each corresponding to six protons, appear at 2.1 and 2.2 ppm and a two-proton singlet for the 9-CH_2 group at 4.1 ppm. The observation that only one set of signals is present for each type of protons and that the methylene signal is a singlet and not an AB-quartet proves that only one stereoisomer is present and that its configuration is C_2. Although **1a**, as in the crystal, is the most likely diastereomer in solution, the NMR data do not allow a distinction between **1a** and **1b**.

The spectrum of **1** is temperature-dependent. At 125°C (in [D_4]-*o*-dichlorobenzene) three resonances for the 9-methylene protons and three pairs of methyl signals have developed. Their ratio is 9:19:11:9:20:9 (cf. Fig. 4). The obvious interpretation is that at higher temperatures the three possible racemic diastereoisomers **1a**, **1b**, and **1c** coexist in solution in approximately a 2:1:1 ratio. If we then assume that the chemical-shift values do not change significantly with temperature, the stereoisomer **1a** seems to be the predominant one, also at higher temperatures. When the NMR solution is cooled to +50°C and kept at this temperature, the signals remain even after 1 hour. The stereoisomerization process is, therefore, rather slow.

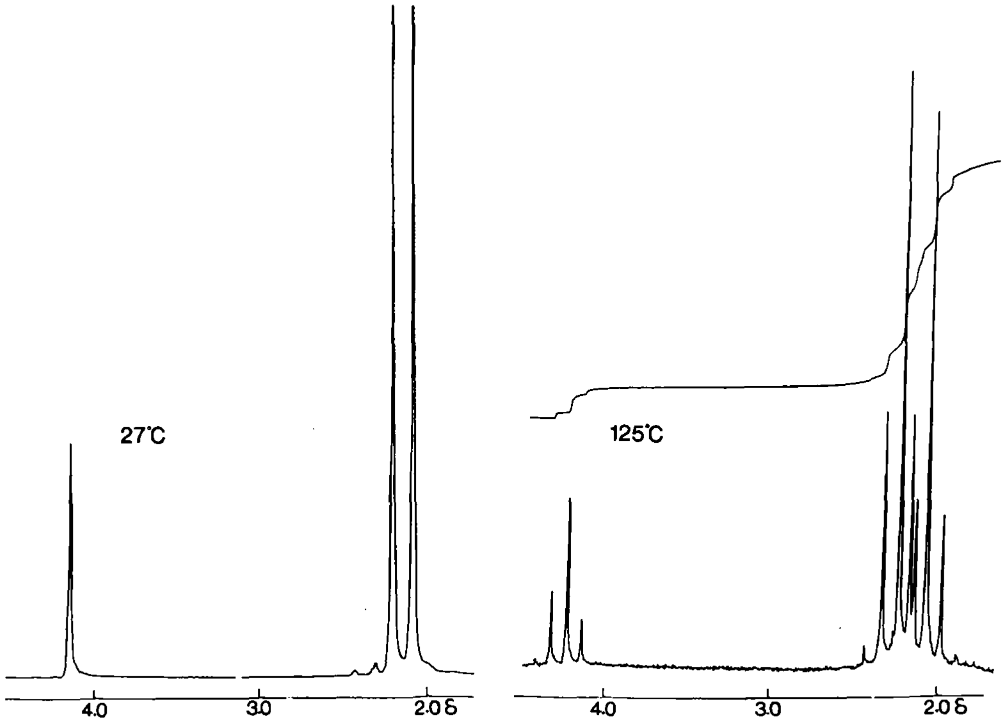

Fig. 4. The methyl and methylene region of the 270-MHz ^{1}H-NMR spectrum of 1 at 27 and 125°C in [D$_4$]-*o*-dichlorobenzene

Protonation Studies on 1

In a detailed study on the protonation of indolizine and some of its alkyl homologues, Reid et al.[19] have established that in acid solution 1*H*- or 3*H*-indolizinium ions, or mixtures of them, are formed. The preferred site of protonation is C-3, when this position is free. Relevant for the study of **1** is their finding that 1,2,3-trimethyl- and 3,5-dimethylindolizine give exclusively the 3*H*-indolizinium ions. This is probably due to steric crowding around the newly formed asymmetric carbon atom.

Bis(1,2-dimethyl-3-indolizinyl)methane (**1**) contains two basic sites and an acid solution of it could contain exclusively mono-protonated or di-protonated ions or a mixture of them. Protonation of "mono"-indolizines, expectedly, causes a downfield shift of the signals of the protons in the six-membered ring from 6.0 – 7.8 to 7.8 – 9.0 ppm[19].

The ^{1}H-NMR spectra of **1** in CF_3CO_2D and in CF_3CO_2H (Fig. 6) display the signals from the protons in the six-membered ring separated into three groups between 7.7 and 9.0 ppm. In $CDCl_3$ the same protons in **1** appear at 6.1 – 7.4 ppm. We therefore conclude that in the acid medium only doubly-charged ions of **1** are present.

We have already demonstrated, that **1** occupies an average C_2 propeller conformation in solution. Protonation of **1a** or **1b** at C-3 and C-3′ creates two new asymmetric carbon atoms giving rise to two pairs of diastereoisomers, not interconvertible by rotation. If the configurations at the two asymmetric centers are the same, 3*R*,3′*R* or 3*S*,3′*S*, the molecule will possess C_2 symmetry for all torsion angles, if these are the same for both rings. Consequently, all corresponding protons in the two halves are equivalent and the NMR spectrum should display four two-proton sets of signals for the ring protons, two six-proton sets for the methyl groups and for the 9-methylene protons, a singlet in CF_3CO_2D and a triplet in CF_3CO_2H, if the exchange of H3 and H3′ is slow. Reid et al.[19] have shown that indolizinium perchlorates do not exchange their C-3 protons in CF_3CO_2D.

If the configurations at the chiral atoms in **1a** are instead opposite, 3*R*,3′*S* or 3*S*,3′*R*, all helical conformations of diprotonated **1** have C_1 symmetry. However, enantiomerization through flipping goes via a transition state, which has C_s symmetry. Therefore, if the barrier is low, the 3*R*,3′*S*/3*S*,3′*R* stereoisomer behaves as a *meso* form in which all corresponding protons, except the 9-methylene ones, are equivalent. These remain diastereotopic and in the NMR spectrum in CF_3CO_2D they should appear as an AB quartet; in CF_3CO_2H each of these signals would be split further into triplets.

In the spectrum of **1** in CF_3CO_2D (Fig. 5) we observe two resonances for the 9-methylene protons, a singlet at 3.42 ppm and a quartet centered at 3.31 ppm. The ratio between them is 53:47. The protonation apparently causes an upfield shift of ca. 1 ppm for these protons. The same was observed by Reid et al.[19] for the 3-methyl protons in 1,2,3-trimethylindolizine.

In CF_3CO_2H, the singlet at 3.42 ppm has changed into a triplet, J = 4.8 Hz, and the quartet to a quartet of triplets, J = 5.5 and 6.2 Hz. The C-3 protons appear as a not particularly sharp two-proton singlet at 5.68 ppm, close to the narrow range of 5.3 – 5.5 ppm reported by Reid et al.[19] for the mono-substituted indolizines. Irradiation at this fre-

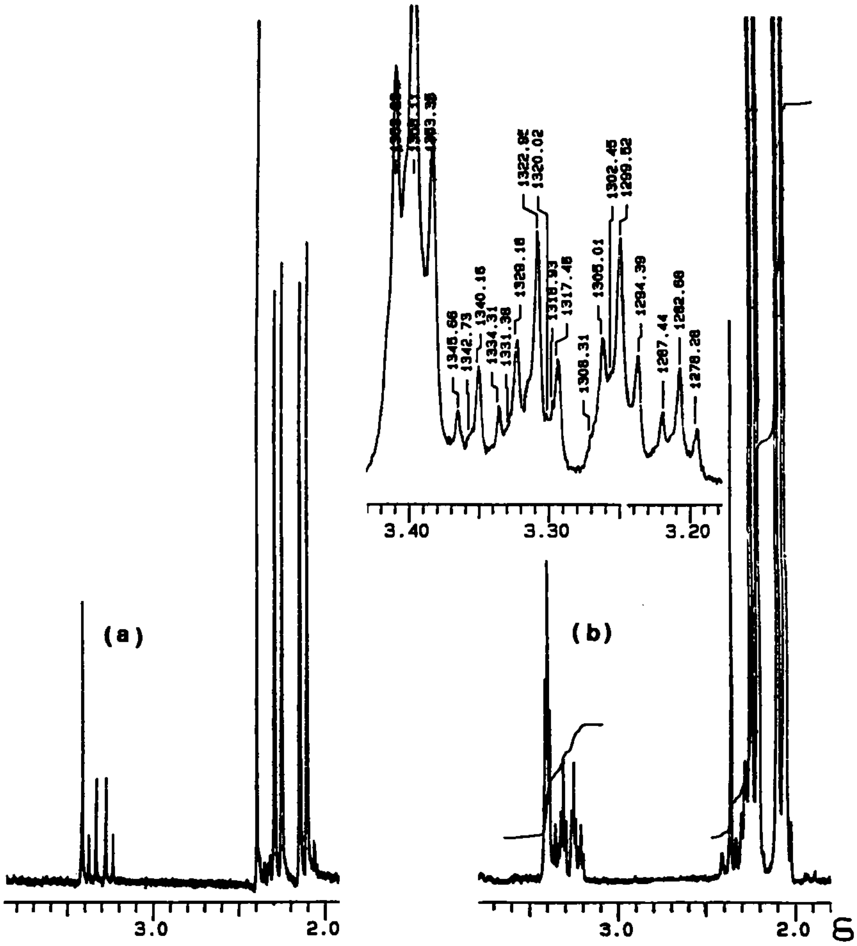

Fig. 5. The methylene and methyl resonances in the 400-MHz ^{1}H-NMR spectrum of the two diastereoisomeric ions formed from **1** in CF_3CO_2D (a) and CF_3CO_2H (b)

quency restores the above-mentioned multiplets to a singlet and a quartet, respectively.

The groups of signals from the ring protons were correlated by decoupling experiments, which are summarized in the Experimental section. Their total number, twenty, excluding signals due to *meta*-couplings, supports the conclusion above, that the C_1 stereoisomer behaves as a *meso* form.

Measurements on Dreiding models indicate that the change of hybridization of C-3 and C-3′ in **1** from sp^2 to sp^3 increases the distance between the 2- and 2′-methyl groups. This would lower the flipping barrier and may explain why the two diastereoisomers are formed in approximately equal amounts. The approach of a second proton to C-3 of the neutral ring of mono-protonated **1** seems to be unhindered from both sides.

Ultraviolet Studies

The ultraviolet spectrum of **1** has been recorded in ethanol and in the same solvent containing perchloric acid. In ethanol the spectrum contains three groups of absorption, some with shoulders and certain fine structure, one of high intensity, ε ≈ 55000, at 252 nm, and two of medium intensity, ε ≈ 4000 – 5000, at 285 – 306 and 264 nm, respectively. In acid medium, the high-intensity band, ε ≈ 40000, remains at 248 nm and only one medium-intensity band, ε ≈ 6000, is visible at 325 nm.

Armarego[20] has reported UV spectra for thirteen alkylindolizines and their salts. 1,2,3-Trimethylindolizine (**2**), which is an ideal "mono"-analogue of **1**, displays spectra with maxima at the same wavelengths and with ε values about half as large as those for **1** in neutral and acidic solution. We therefore conclude, that no substantial interaction exists between the two rings in **1**, or in its diprotonated ion.

Armarego[20] also reported, that the long-wavelength bands of 1*H*-indolizinium ions appear at ca. 275, while 3*H*-indolizinium ions absorb at 325 nm. Our UV results for **1** are in agreement with 3-protonation, which is also proved conclusively by the NMR studies.

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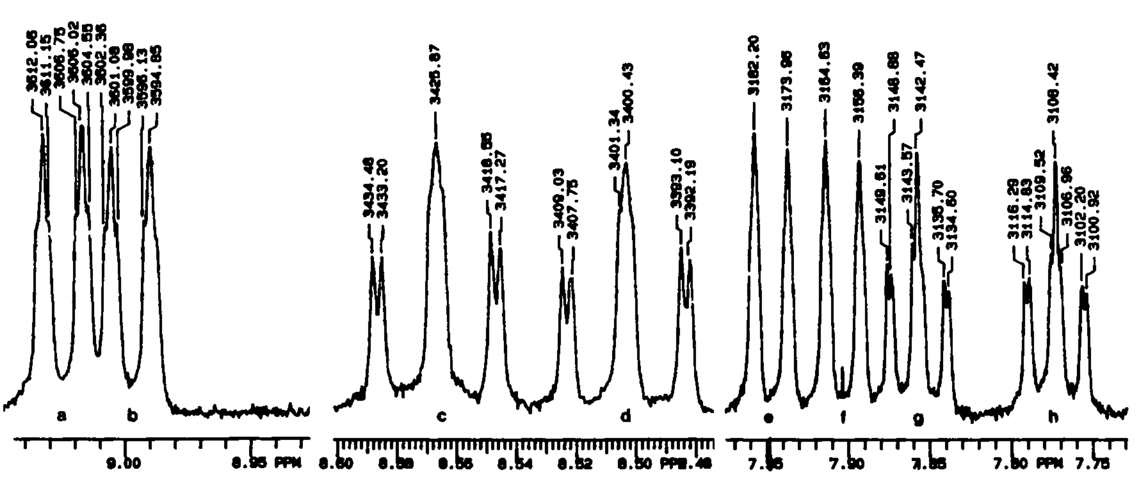
Experimental

NMR spectra: Bruker WH 270 and Varian XL 400 MHz spectrometer, $CDCl_3$ as solvent, TMS as internal reference. – Electronic spectra: Solvent ethanol, Cary-Varian Model 210 spectrometer. – Mass spectra: GEC-AEI 902 mass spectrometer. – Column chromatography: silica gel (0.063 – 0.2 mm; Merck).

Synthesis of Bis(1,2-dimethyl-3-indolizinyl)methane (**1**): To a solution of 2.00 g (13.8 mmol) of 1,2-dimethylindolizine in 12 ml of ethanol, 0.19 ml of 40% aqueous formaldehyde was added. After a



Irradiation frequencies	Effect at
3608 Hz	g(t → d)
3426 Hz	e(d → s) and g(t → d)
3108 Hz	b(d → s) and d(t → d)

Fig. 6. Expansion of the H5-H8 region in the 400-MHz ^{1}H-NMR spectrum of **1** in CF_3CO_2D (concentration: 8 mg in 0.8 ml)

few seconds a precipitate was formed. It was separated by filtration, dried, and then dissolved in ether and passed through a short column of silica gel. After evaporation of the ether, 1.88 g (90%) of white crystals of **1**, m.p. 168°C, was isolated. – UV (ethanol): λ_{max} (log ε) = 238 nm (sh; 4.54), 246 (sh; 4.59), 252 (4.74), 285 (3.72), 294 (3.77), 306 (3.79), 367 (3.56); (ethanol/$HClO_4$): 244 (sh; 4.49), 248 (4.60), 293 (3.54), 305 (3.79), 382 (3.79). – MS (EI, 70 eV): M^+ 302.1768; Calcd. for $C_{21}H_{22}N_2$ 302.1783.

Decoupling Experiments on the H5-H8 Protons in **1** (Fig. 6)

The resonances a, c, e, and g belong to the two rings in one diastereoisomer and b, d, f and h to the two rings in the other one.

X-Ray Structural Determination of **1**: Crystals of **1** were obtained from acetonitrile/methanol (4:1). The solution, saturated at 60°C (110 mg of **1** in 25 ml of solvent), was left for 24 h. The crystals, which had precipitated, were separated and dried at room temperature under vacuum. Long needles, 0.2 × 0.1 × 0.2 mm, were chosen for the X-ray-diffraction measurements. The crystals are monoclinic, space group $P2_1/c$ with a = 9.987(7), b = 20.85(1), c = 8.699(6) Å, β = 106.67(5)°, V = 1735(2) Å^3, $F(000)$ = 648, $d_{calcd.}$ = 1.16 mg m^{-3} for Z = 4 ($C_{21}H_{22}N_2$, M_r = 302.4), μ(Mo-K_α) = 0.7 cm^{-1}. Intensities were measured for $3.5 \leqslant 2\sigma \leqslant 55.0°$, a total of 3742 reflexions being measured. Of the 2516 unique reflexions measured, 1556 had $I \geqslant 3.0\sigma$ (I) and were considered observed. The structure was solved with MULTAN-80, which revealed the positions of all non-hydrogen atoms. The hydrogen atomic positions were found after least-squares refinement and difference Fourier analysis. The final full-matrix refinement cycle included anisotropic temperature factors for the non-hydrogen atoms and fixed isotropic values for the hydrogen atoms. The final R value was 0.059 (R_w = 0.069). The number of refined parameters was 264 and the intensity of the highest peak in the last electron density map was 0.5 eÅ^{-3}. Fractional coordinates and temperature factors and anisotropic factors for the non-hydrogen atoms are available on request from the Director of the Cambridge Crystallographic Data Center, University Chemistry Laboratory, Lensfield Road, Cambridge CB 2, 1 EW, and lists of structure factors from the authors.

CAS Registry Numbers

1: 6768-60-1 / **2**: 1761-24-6 / 1,2-dimethylindolizine: 1125-77-5 / formaldehyde: 50-00-0

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