Diazepines. Part 30.[1] A Comparison between the Extent of Delocalisation of Electrons in a Vinamidine and its Protonated Form. Crystal and Molecular Structure of Two 2,3-Dihydro-1,4-diazepines

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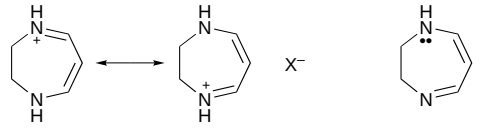
An X-ray study of two 2,3-dihydro-1,4-diazepine bases shows that their vinamidine systems are made up of alternate single and double bonds, in contrast to the derived monocations which contain fully delocalised vinamidinium structures.

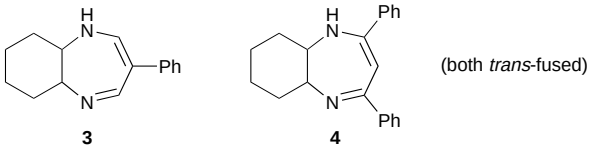
X-Ray studies of a number of 2,3-dihydro-1,4-diazepinium salts (**1**) have been carried out[1,2] and show clearly the extensive delocalisation of π-electrons in the vinamidinium portion of the molecules. The salts also have chemical and spectroscopic properties typical of a delocalised system,[2] and they have been described as quasi-aromatic molecules.



1 **2**

Calculations based on pK data suggest that the cation **1** has a stabilisation energy of about 19 kcal mol^{-1} and that the corresponding dihydrodiazepine base **2** has a stabilisation energy of 12–14 kcal mol^{-1}.[3] This difference is reflected in the very high basicity of dihydrodiazepines.[4] NMR spectra of both the bases and cations indicate the total equivalence of N(1) and N(4) and of C(5) and C(7) on the NMR timescale; this implies that in the bases there is in solution a very rapid transfer of a proton between the two nitrogen atoms.

In order to investigate further the extent of delocalisation of electrons in the vinamidine system in a dihydrodiazepine base an X-ray crystallographic study has been made of the two bases **3** and **4** (Figs. 1 and 2).



3 **4** (both *trans*-fused)

Good crystalline samples of dihydrodiazepine bases are difficult to obtain, partly due to their high basicity (pK_a = 13–14), but proved to be obtainable in the cases of **3** and **4**; X-ray data were available for related cations, making relevant comparisons possible. X-Ray studies on these cations showed that 2,3-fused cyclohexane rings appear to have little effect on the structure of the unsaturated portions of the molecules and do not distort them.[1] The only previous X-ray studies on 2,3-dihydro-1,4-diazepine bases involved molecules wherein heterocyclic rings were annelated to the vinamidine system.[5,6]

Experimental

The dihydrodiazepine bases were obtained from their perchlorate salts by suspending the latter in ether and treatment with 10 M sodium hydroxide. For details see full text.

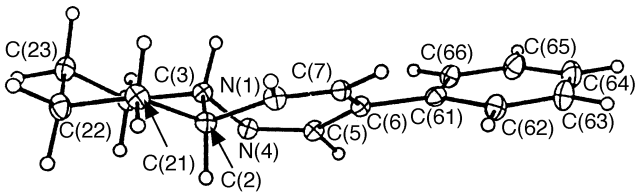


Fig. 1 X-Ray crystal structure of compound **3**

Crystal Data. 6-*Phenyl Derivative*.—$C_{15}H_{18}N_2$; **3**, M = 226.31, orthorhombic, a = 12.318(5), b = 7.460(2), c = 25.860(3) Å, U = 2467.4 Å^3 space group *Pbca*, Z = 8, D_{calc} = 1.218 g cm^{-3}, F(000) = 976, colourless slab 0.50 × 0.50 × 0.10 mm^3, μ(Mo-Kα) = 0.07 mm^{-1}, T = 150.0(2) K.

5,7-*Diphenyl Derivative*.—$C_{24}H_{30}N_2O$; **4**, Me_2CHOH, M = 362.50, monoclinic, a = 10.1439(7), b = 16.1623(9), c = 13.1187(7) Å, β = 94.551(5)°, U = 2144.0 Å^3, space group $P2_1/c$, Z = 4, D_{calc} = 1.123 g cm^{-3}, F(000) = 784, colourless block 0.45 × 0.31 × 0.31 mm^3, μ(Cu-Kα) = 0.527 mm^{-1}, T = 220.0(2) K.

Data Processing.—Both data sets were collected on a Stoe Stadi-4-diffractometer equipped with an Oxford Cryosystems variable temperature device. Data for **3** were collected in the range $5 \leq 2\theta \leq 50°$ using Mo-Kα radiation (λ = 0.71073 Å) and $\omega - \theta$ scans. Both structures were solved by direct methods and refined by full matrix least-squares against F^2. H-Atoms in **3** were located in ΔF maps and refined freely with isotropic displacement parameters; those in **4** were mostly placed in calculated positions and allowed to ride on the atoms to which they are bonded. The H-atom on N(1) was located in a ΔF map and its positional parameters refined freely. In **4** there is a two-fold disorder in the cyclohexane ring and in the isopropanol of crystallisation and in each case the alternative components were restrained to be geometrically similar. At convergence for **3** $R1$ = 4.82% [based on F and 1576 data with $F > 4\sigma(F)$] and wR_2 = 12.50% (based on F^2 and all 2146 unique data) for 227 parameters. For **4**, R_1 = 5.94% (2452 data) and wR_2 = 17.22% (3141 data) for 292 parameters. The final ΔF extrema were ±0.19 e Å^3 for **3** and +0.23/−0.27 for **4**. Bond lengths and bond angles are given in Tables 1 and 2 (see full text).

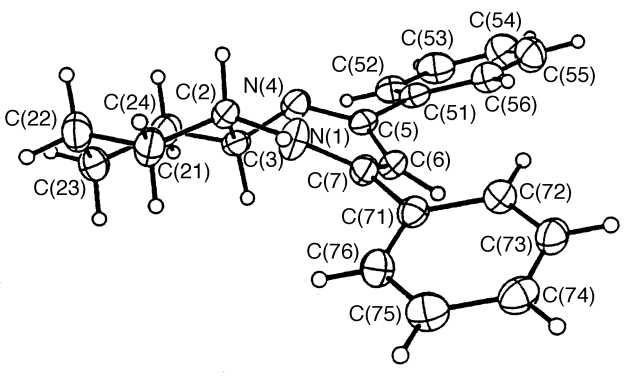


Fig. 2 X-Ray crystal structure of compound **4**

*To receive any correspondence.

Table 3 Some comparative bond lengths

Compound	Bond length Å			
	N(1)–C(7)	C(7)–C(6)	C(6)–C(5)	C(5)–N(4)
6-Phenyl-**1** (cation)[1]	1.315(4)	1.391(4)	1.405(4)	1.305(4)
Cation from **3**[1]	1.318(4)	1.393(4)	1.388(4)	1.322(4)
3 (base)	1.335(3)	1.364(3)	1.451(3)	1.289(2)
5,7-Diphenyl-**1** (cation)[13]	1.335(6)[a]	1.384(6)	1.406(6)	1.328(6)[a]
4 (base)	1.349(3)	1.360(3)	1.430(3)	1.294(3)

[a]These N(1)–C(7) and C(5)–N(4) bonds are longer than usual, see refs. 1 and 14.

Discussion

There are striking differences in the bond structure of the bases compared to the cations. In contrast to the delocalised structure of the vinamidinium cation, the bonds in the vinamidine systems of the dihydrodiazepine bases are alternately single and double (see Table 3). There is, however, little difference between the bond angles in the bases and cations.

Whereas the vinamidinium systems have bond distances characteristic of a fully delocalised π-electron system, the bonds in the vinamidine systems in the dihydrodiazepine bases alternate in length and are reminiscent of an open-chain push-pull conjugated system rather than of a delocalised system. For example, in two enaminals[15] the bond distances of the N–CH= bonds are 1.334(2) and 1.354(2) Å and of the CH=CH bonds are 1.363(3) and 1.355(2) Å.

In the bases and the cations the conjugated vinamidine and vinamidinium moieties are both in the form of shallow helices; there is very little difference between them in their deviations from planarity, *e.g.* for **3** (base), deviation from planarity = 0.078 Å, in the cation derived from **3** 0.082 Å. Thus the difference in their bond structures cannot be ascribed to any steric interference to conjugation in the base.

This large difference between the dihydrodiazepine bases and their cations is interesting in that both species are made up inherently from the same six-electron push-pull system, but the symmetry and the possibility for delocalisation of charge in the cation, but not present in the base, obviously confer quite different types of structure on the two species. Whereas the vinamidinium systems of the cations are inherently symmetrical, the vinamidine systems of the bases are not and can only achieve symmetry in solution by a very rapid 1,5-shift of a hydrogen atom between the 1- and 4-nitrogen atoms.

In the crystal the 2,3-cylohexano-6-phenyldihydrodiazepine molecules are lined in chains through N(1) ··· H ··· N(4) hydrogen bonds between neighbouring molecules. In the 5,7-diphenyl analogue the NH is hydrogen bonded to the oxygen atom of a molecule of propan-2-ol of crystallisation and N(4) is hydrogen bonded to the $HOCH(Me)_2$ group of the propan-z-ol.

Technique used: X-Ray diffraction

Tables 1 and 2: Bond lengths and bond angles for **3** and **4**

Appendix: Crystal data for **3** and **4**

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