HETEROCYCLES, Vol 24, No 2, 1986

A NOVEL DIMERIZATION OF A PYRIDINIUM RING INVOLVING LINKAGE OF THE 2,5-POSITIONS OF ONE RING TO THE 4',3'-POSITIONS OF ANOTHER

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Abstract - Decarboxylative dimerization of 1-(2'-pyridyl)-2-carboxy-4,6-diphenylpyridinium tetrafluoroborate monohydrate yields a novel cage coumpound. The structure is elucidated by X-ray and nmr spectroscopic methods.

1-Substituted pyridinium-2-carboxy betaines are known to undergo decarboxylation on heating and we have studied such reactions in a number of cases.[1-5] The present paper describes a novel dimerization reaction induced by the pyrolysis of such a betaine.We have previously described[1] the preparation of 1-(2'-pyridyl)-2-carboxy-4,6-diphenylpyridinium tetrafluoroborate and the hydrolysis of the ester (1) under mild conditions to yield the corresponding betaine (2) which was isolated as the monohydrate. This betaine on refluxing in methanol or ethanol underwent[1] easy decarboxylation to yield the corresponding 2-methoxy- (3) and 2-ethoxy-1,2-dihydropyridines (4). However, refluxing the betaine monohydrate in dry benzene (attempts to obtain the anhydrous betaine by azestropic removal of water failed) gave a colourless solid which analysed for $C_{44}H_{34}N_4O$ (corresponding to twice the betaine less $2CO_2$ plus H_2O).

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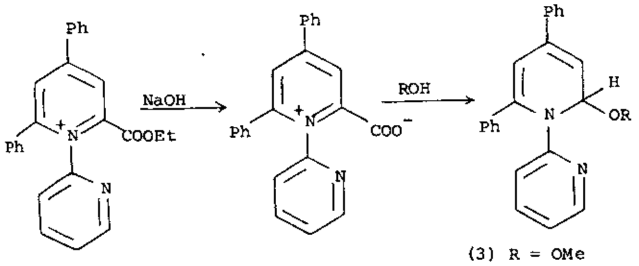
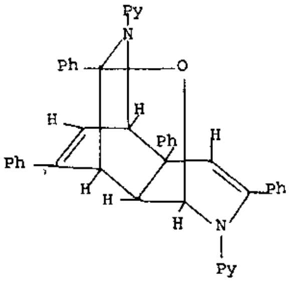
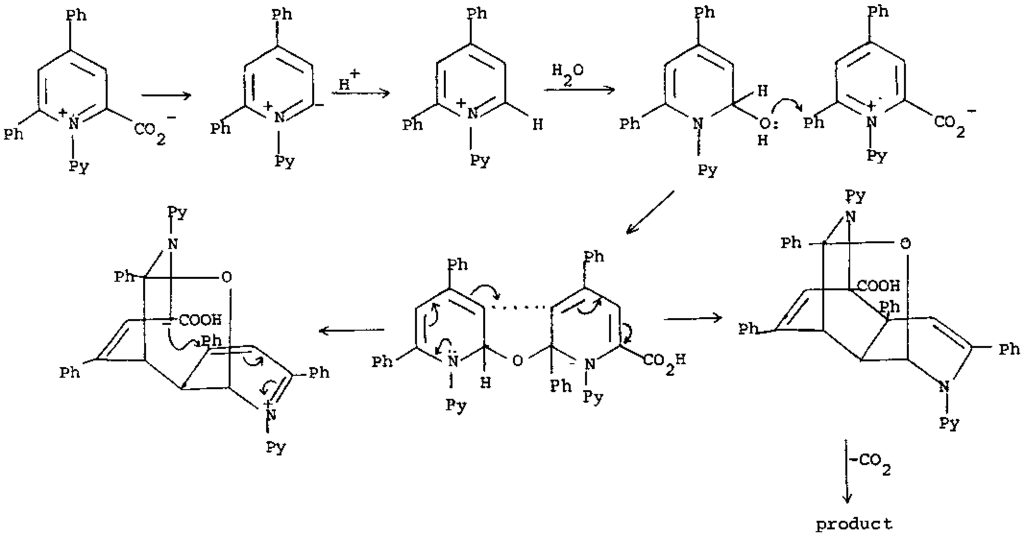


(1) (2) (3) R = OMe (4) R = EtO



(5)

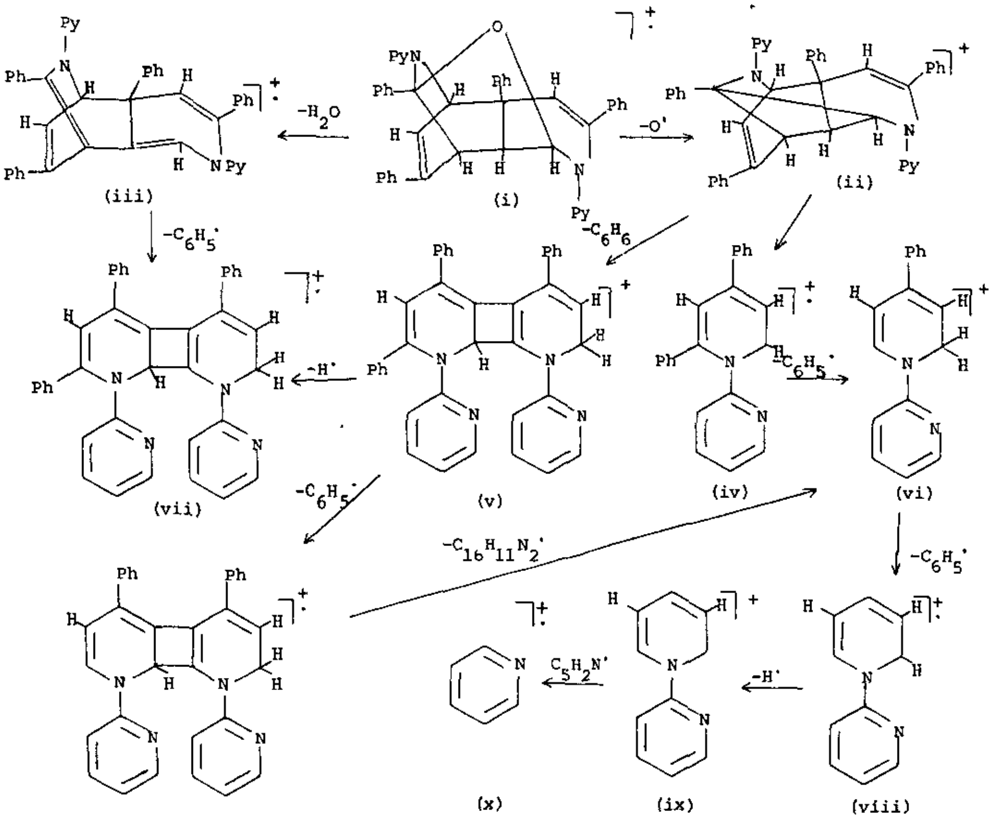
X-Ray crystallographic analysis showed the product to possess structure (5). A possible mechanism of formation of (5) is shown in Scheme 1. It involves an unusual cycloaddition reaction of the 2,5-positions of one pyridine ring to the 3,4-positions of another. It appears likely that the ring which reacts at the 3,4-positions is in the form of the pseudo-base, whereas the other ring reacts in the form of the pyridinium cation. The cycloaddition is then followed by addition of the hydroxy group of the pseudo-base to the 6-position of the other pyridine ring. Cycloadditions of the 2,5-positions of one pyridine ring to the 3,4-positions of another have apparently previously not been reported. Cage compounds have been formed from pyridine rings in several instances including the reaction of 1-vinylpyridinium cation with hydroxide[6] and by dimerization of 3-oxidopyridiniums.[7]



Scheme 1: Mechanism of Dimer Formation

The chemical ionization mass spectrum of the product supports the structure shown. The principal fragmentation pathway is outlined in Scheme 2. Elimination of H_2O from the molecular ion (i) at m/z 634 gave a peak of strong intensity at m/z 616, represented as (iii). Elimination of an oxygen atom from (i) gave moderately intense fragment ion (ii), which on loss of benzene gave the intense ion peak (v) at m/z 540. Fission of (ii) yields the strong ion peak (iv) at m/z 309 which loses a phenyl radical to give the base peak (vi) at 232 which can also be obtained from (vii) by successive loss of C_6H_5 and of the $C_{16}H_{11}N_2$ moiety. Fragmentation of (vi) gives rise to the species (viii) at m/z 155 by loss of C_6H_5. Species (viii) loses hydrogen to give (ix) at m/z 154 which in turn loses C_5H_2N to form the strong pyridine ion peak (x) at m/z 78.

Scheme 2: Mass Spectral Fragmentation



The ^{13}C NMR spectrum shows the presence of a total of 34 signals of which 28 lie in the region expected for sp^{2} hybridized carbon atoms and 6 in the region expected for sp^{3} hybridized. The J-modulated spin echo experiments indicate that of the 6 aliphatic carbon atoms, 2 are quaternary and 4 are methines. Of the sp^{2} hybridized carbon signals, 8 are quaternary and 20 are methines. The numbers of signals of each type correspond to those expected for structure (5). The assignments have been made as shown in the Table. Those for the sp^{2} hybridized carbons are fairly straightforward; see above and also Table 1.

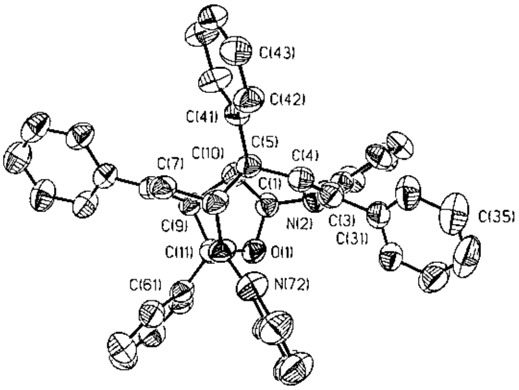
Table 1 Proton and Carbon-thirteen Nmr Data [a]

^{1}H nmr					^{13}C nmr[b]					
Atom	Delta	H	m	J	Atom	Delta	m	Atom	Delta	m
H-10	3.264	1	t	4.54	C_1	87.115	d	C_{21}	155.726	s
H-9	3.785	1	dd	4.54,3.60	C_3	144.890	s	C_{23}	148.055	d
H-4	5.648	1	s	-	C_4	123.653	d	C_{25}	136.537	d
	6.163-6.224	2	m	-	C_5	51.254	s	C_{71}	155.621	s
	6.655-6.699	1	m	-	C_7	126.07	d	C_{73}	146.399	d
	6.742-6.774	2	m	-	C_8	140.666	s	C_{75}	135.590	d
	6.838-6.997	2	m	-	C_9	56.807	d	C_{31}	138.149	s
phenylprotons	7.001-7.416	20	m	-	C_{10}	44.233	d	C_{41}	135.822	s
H-23	8.311-8.337	1	m	-	C_{11}	93.87	s	C_{51}	137.913	s
H-73	7.877-7.903	1	m	-				C_{61}	138.036	s
	7.63	H_2O		-						

[a] Numbering as in X-ray structure. [b] Most prominent ^{13}C resonances; ^{13}C chemical shifts of basic ring skeletons (assignments is based on ^{13}C - ^{1}H two dimensional nmr experiment and chemical shift consideration).

The high resolution proton nmr analysis at 200, 300 and 360 MHz was not straight forward. This is due to extensive overlap of the phenyl protons with those of the pyridyl and mutual overlap of the aliphatic proton signals. However, salient features due to the pyridyl ring protons are evident. Thus the alpha-protons appeared at ca. delta 7.8 and 8.3 ppm. Their assignment (Table 1) was based on electronic and steric considerations and supported by two dimentional Cosey (H-H conectivity) experiments at 360 and 500 MHz. Based on the above data, together with homo spin-decoupling experiments, the high field region of the H-1 nmr was unambigiously assigned. Thus H-10 appeared as a triplet at delta 3.264 ppm with J = 4.5 Hz, this is coupled to H-9, which itself resonated at delta 3.785 as a AB double doublet with J = 4.54 and 3.60 Hz. The signal due to the H-4 resonance appeared, as expected, as a single line at delta 5.648. Assignment of the remaining protons was ambiguous. The ir spectrum showed a band characteristic for dihydropyridines at 1645 cm^{-1}.

Compound 5 crystallizes in the space group $P2_1/C$ with a=17.176(1), b=17.214(3), c=11.597(2) A^{o} and B=103.72(1)^{o}. With four molecules per cell, D_c is 1.264 g cm^{-3} versus 1.27 g cm^{-3} measured. The structure was solved and refined using the SHELXTL system. The R and Rw were 0.068 and 0.064 for the 2890 reflections used in the analysis.



A drawing of the molecule with the atomic numbering is given in the Figure. The average bond distances in the molecule are close to the expected values. The distances C(3)-C(4) of 1.315 A^{o} and C(7)-C(8) of 1.329 A^{o} establish the location of the double bonds. The O(1)-C(1)-C(10)-C(9)-C(11) ring has an envelope conformation with C(9) the flap. The six-membered rings C(5)-C(6)-N(12)-C(11)-C(9)-C(10), C(6)-C(7)-C(8)-C(9)-C(11)-N(12), and C(5)-C(6)-C(7)-C(8)-C(9)-C(10) are in the boat conformation with the C(6) and C(9) atoms up. The ring C(1)-N(2)-C(3)-C(4)-C(5)-C(10) is in a half-boat conformation with C(1) the up atom.

EXPERIMENTAL

^{1}H Nmr spectra were recorded on a Varian HA-100 IBM 200 SY, Nicolet 300 NT and 360 NB Spectrometers using tertramethylsilane as an internal standard. ^{13}C Nmr spectra were obtained on a Jeol JNM-FX 100 and a Nicolet 300 NT spectrometers, and chemical shifts were determined relative to delta $CDCl_3$. Ir spectra were obtained on a Perkin Elmer 283 B grating spectrophotometer for samples in $CHBr_3$ solutions. High resolution mass spectra were obtained on a Hitachi Perkin-Elmer RMH-2 and a VG 70-70 Micromass double focusing spectrometer interfaced with a Kratos DS-50-S data system. Melting points were measured on a Reichert hot-stage microscope and are uncorrected.
The following compounds were made using literature methods: 2-ethoxycarbonyl-1-(2'-pyridyl)-4,6-diphenylpyridinium tetrafluoroborate (1), mp 193 ^{o}C (lit.,[1] mp 192-193 ^{o}C);

1-(2'-pyridyl)-2-carboxy-4,6-diphenylpyridinium betaine (2), mp 131 ^{o}C (lit.,[1] mp 130 ^{o}C).

Pyrolysis of 1-(2'-Pyridyl)-2-carboxy-4,6-diphenylpyridinium Betaine (2) in Benzene.- 1-(2'-Pyridyl)-2-carboxy-4,6-diphenylpyridinium betaine (2) (1.0 g, 0.08 mol) was refluxed in dry benzene (20 ml) for 5 h. The solvent was evaporated, and the residue triturated with EtOH to give 3,5,8,11-tetraphenyl-2,12-di-(2-pyridyl)tetracyclo$[7.2.1.^{6,11}0^{5,10}]$-1,11-oxa-2,12-diazatrideca-3,7-diene (5) (0.8 g), m.p. 204-206 ^{o}C (Found: C, 82.52; H, 5.48; N, 8.55. $C_{44}H_{34}N_4O$ requires C, 83.28; H, 5.36; N, 8.83). IR ($CHBr_3$) 1650, 1590, 1570, 1495, 1475, 1435(d), 1370(d), 1330, 1260(d), 1060, 1030, 1020, 970, 930, 860, 840, 765, 720 cm^{-1}. ^{1}H Nmr delta ($CDCl_3$) 3.264 (1H, t, J=4.54), 3.785 (1H, dd, J=4.54, 3.60), 5.648 (1H, s), 6.163 - 6.224 (2H, m), 6.493 - 6.545 (2H, m), 6.665 - 6.699 (1H,m), 6.742 - 6.774 (2H,m), 6.838 - 6.997 (2H,m), 7.001 - 7.416 (20H, m), 8.311 - 8.337 (1H, m), 7.877 - 7.903 (1H, m), ^{13}C Nmr delta ($CDCl_3$): 44.23(d), 51.25(s), 55.20(d), 87.12(d), 93.87(s), 112.19(d), 113.06(d), 114.80(d), 116.06(d), 123.65(d), 125.19(d), 126.07(d), 126.32(d), 126.48(d), 127.00(d), 127.37(d), 127.51 (d), 127.65(d), 127.74(d), 128.33(d) 129.56(d), 135.59(d), 135.82(d) 136.54(d), 137.91(s), 138.04(s), 138.15(s), 140.67(s), 144.89(s), 146.40(d), 148.06(d), 155.62(s), 155.73(s). Ms (CI) : m/e 634.2762 (relative intensity); M^{+} 634 (0.2), 617 (15), 616 (25), 542 (8), 541 (18), 540 (30), 539 (15), 538 (10), 525 (18), 524 (33), 463 (16), 462 (15), 448 (15), 445 (17), 442 (9), 311 (33), 310 (68), 309 (88), 296 (20), 233 (68), 232 (100), 231 (32), 230 (27), 207 (9), 206 (7), 202 (10), 195 (31), 194 (10), 181 (15), 155 (10), 154 (16), 105 (37), 95 (49), 94 (84), 79 (23), 78 (59), 77 (18), 76 (4).

ACKNOWLEDGEMENTS

We thank Dr. M.A. Battiste for discussion, Dr. LeRoy Johnson for preliminary 2D spectra, Dr. Furst and Dr. Menger at the University of Pennsylvania and Emory University respectively for nmr facilities, M.R. Davis and Dr. R.W. King for mass spectra, and NSF for financial support of the Nicolet 300 NT instrument and the Nicolet X-ray diffractoometer (CHE-8316675).

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Received, 1st October, 1985