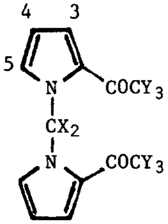
Tetrahedron Letters No. 50, pp 4995 - 4998.
0040-4039/78/1208-4995$02.00/0

MASS-SPECTRAL REARRANGEMENT, PHOTO-ISOMERIZATION AND PHOTO-SOLVOLYSIS OF BIS(2-ACETYLPYRROL-1-YL)METHANE

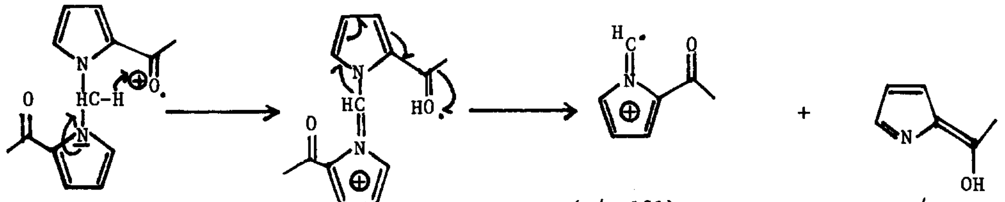
Otto H. Houwen and Donald F. Tavares*
Department of Chemistry, The University of Calgary
Calgary, Alberta, Canada T2N 1N4

Although the relationship between photochemical and mass-spectrometric reactivity has been widely discussed,[1] in the pyrrole series only one report, on the dealkylation of N-alkyl-2,4-diphenylpyrroles, has appeared.[2] We have studied an N-substituted derivative of 2-acetylpyrrole, in which intramolecular hydrogen abstraction by the carbonyl oxygen may compete with the migrations and cleavage usually displayed[3,4] by N-substituents.



1 X = Y = H
2 X = D Y = H
3 X = H Y = D

Bis(2-acetylpyrrol-1-yl)methane **1** (m.p. 180-181°, NMR: δ7.37 (H_5), 6.95 (H_3), 6.09 (H_4), 6.97 (CH_2), 2.41 (CH_3); ring-proton coupling constants, measured on **2**: $J_{3,4}$=4.1, $J_{4,5}$=2.6, $J_{3,5}$=1.6 Hz), and the dideuterated analogue **2** were prepared[5] by reaction of 2-acetylpyrrol-1-yl potassium with methylene iodide or methylene iodide-d_2. Deuterium exchange of **1** (NaOD in D_2O/THF) gave the hexadeutero-compound **3**. In the 70 eV mass spectrum of **1** only three peaks have a relative intensity greater than 25%. They occur at m/e 43 (67%, acetyl ion), m/e 121.0527 (95%, calcd. for C_7H_7NO: 121.0528), and m/e 122.0602 (100%, calcd. for C_7H_8NO: 122.0606). In the spectrum of **3** (97 atom %D) the two major peaks have shifted to m/e 124 (100%) and 125 (94%). The m/e 122 peak (125 in the case of **3**) results from cleavage of the methylene-nitrogen bond with loss of a 2-acetylpyrrol-1-yl radical. The shift of m/e 121 to 124, going from **1** to **3**, proves that the hydrogen atom constituting the formal difference between m/e 121 and 122 does not originate from an acetyl group (in which case a shift to m/e 123 would occur), but from the methylene bridge. The fragmentation of **1** to m/e 121 is accompanied by a weak metastable peak at m/e 63.7 (calculated 63.66 vs. 64.71 for the fragmentation to m/e 122), shifting to the expected value of 65.2 in the case of **3**. A decrease of the electron energy to 15 eV has the effect that the m/e 121 peak becomes the base-peak, while the m/e 122 peak is reduced to 11%, close to the natural abundance ratio (121 + 1)/122 of 8.1%. No other peaks, except for the molecular ion, were present. Relative enhancement at lower electron impact energies and the occurrence of metastable peaks are characteristic for rearrangement reactions, which leads us to the following rationalization:

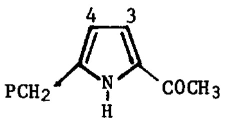


(m/e 121)

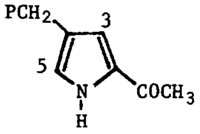
4

Several other N-alkyl substituted 2-acetylpyrroles also undergo this "M-109 rearrangement",[6] typified by the loss of the 2-acetylpyrrole-enol 4 (mass 109).

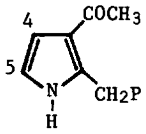
Irradiation of 1 in dioxane (0.013M, Ar atmosphere) on a preparative scale in a quartz flask at 254 nm (Rayonet Photochemical Reactor) gave a complex mixture, which was separated by classical chromatography on alumina, followed by preparative HPLC (Micropak Si-10, 10% isopropanol in hexane). The reaction could be followed quantitatively by HPLC (calibrated UV detection at 280 nm). The concentrations of all products increased steadily during the irradiation; thus, after 70 hours, photoisomers 5, (m.p. 174-175.5°; 12%), 6 (m.p. 137.5-139°; 2%), 7 (m.p. 136-137°; 1%), and 8 (m.p. 82.5-83.5°; 5%) were formed.[5] The structures of these compounds were determined on the basis of their mass, IR, UV, and NMR spectra, details of which will be published in the full paper. The NMR assignments of 5, 6, and 7 are given in Table I and were supported by D_2O exchange, spin decoupling and analysis of the coupling constants of the ring protons.[7] The NMR spectrum of 8 showed peaks at δ9.8 (NH), 6.93 ($H_3 + H_5 + H_3' + H_5'$), 6.23 (H_4 or H_4'), 6.09 (H_4' or H_4), 4.68 (t, J=6.7, β-CH_2), 3.27 (t, J=6.7, α-CH_2), and 2.39 (CH_3). In addition to these products, 2-acetylpyrrole 9 (4%), starting material 35%) and 41% of intractable polar material were present.



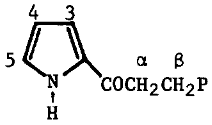
5



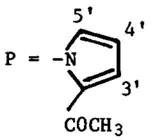
6

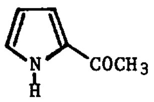


7

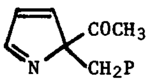


8

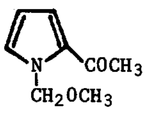




9



10



11

TABLE I. Proton NMR Chemical Shifts for Compounds 5, 6, and 7.

	NH	H_3	H_4	H_5	H_3'	H_4'	H_5'	CH_2	CH_3	
5	10.2	6.75	6.15	-	6.95	6.15	6.95	5.45	2.47	2.38
6	9.6	6.78	-	6.96	6.96	6.13	6.96	5.42	2.38	2.32
7	10.3	-	6.60	6.46	6.97	6.09	7.52	5.76	2.43	2.39

Products 5, 6 and 9 are the rearrangement and cleavage products usually observed for N-substituted pyrroles.[3,4] The formation of 7 can be explained by invoking initial formation of the 2H-pyrrole 10 in which the acetyl group migrates preferentially over the (2-acetylpyrrol-1-yl)-methyl group (a heterocyclic benzyl analogue) in a fast thermal rearrangement.

Irradiation of 2 in methanol (0.0064M) on a preparative scale under the same conditions gave three major products: 5, 9 and the ether 11,[8] along with small amounts of 6 and 8. The distribution of deuterium in the methylene groups of 2 (both in starting- and in recovered material) and in 5 and 11 is given in Table II.[9]

TABLE II. Isotopic Distribution in Methylene Groups of Compounds 2, 5, and 11 from Irradiation of 2 in Methanol.

	2 starting	2 recovered	5	11
% CH_2	17	14	26	28
% CHD	21	43	38	39
% CD_2	62	43	36	33
% H, total	28	36	48	48

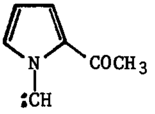
For a comparison of the relative yields in both solvents, solutions of 1 in dioxane (0.013M) and methanol (0.0065M) were irradiated in 10 mm quartz tubes for 4 hours. The concentrations of products determined by HPLC are given in Table III.

TABLE III. Concentrations (μg/ml) of Products from 1 After 4 Hours of Irradiation.

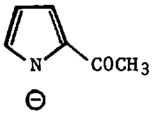
Solvent	Starting conc. of 1 (μg/ml)	5	6	8	9	11
Dioxane	3.0×10^3	181	21	72	47	0
Methanol	1.5×10^3	271	20	36	111	71

If a photochemical analogue of the mass spectral "M-109 rearrangement" were operative, enol 4 and carbene 12 would be expected as the primary products, in which case the starting material 2, with CD_2 bridge, would be transformed into photoproducts having not more than one D atom.

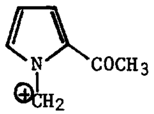
However, since it is clear from Table II that more than one-half of the doubly deuterated methylene groups are carried over unchanged into products 5 and 11, we conclude that 12 is definitely not important in the mechanism leading to these products. The increased H/D ratio in recovered 2 indicates that some hydrogen abstraction does occur, though the mechanism is not clear.



12



13



14

The close similarity of the deuterium distributions of 5 and 11 (Table II) suggests that both are formed from a common intermediate which is sufficiently electrophilic to react with methanol. We propose a heterolytic photo-dissociation of 1 into the ion-pair 13 + 14 to account for our observations. To our knowledge, heterolysis is unprecedented in pyrrole photochemistry. The N-substituted pyrroles[2,10] and indoles[11] which have been irradiated in methanol or ethanol gave only cleavage and/or rearrangement products. In none of the reported cases was there any evidence for ionic intermediates in the mechanism and no methyl or ethyl ethers were found. Further work on our proposal for the mechanism of photo-rearrangement and photo-solvolysis will be reported later in the full paper.

Acknowledgement

O. H. H. thanks the National Research Council of Canada for a Postgraduate Scholarship and the University of Calgary for a Dissertation Fellowship.

References and Footnotes

1. R. C. Dougherty, Fortschr. Chem. Forsch., 45, 93 (1974).
2. A. Padwa, R. Gruber, D. Pashayan, M. Bursey, and L. Dusold, Tetrahedron Letters, 3659 (1968).
3. J. M. Patterson, J. D. Ferry, and M. R. Boyd, J. Am. Chem. Soc., 95, 4356 (1973).
4. J. M. Patterson and D. M. Bruser, Tetrahedron Letters, 2959 (1973).
5. Satisfactory elemental analyses and/or high-resolution mass spectra were obtained for new compounds described here.
6. O. H. Houwen and D. F. Tavares, to be published.
7. T. J. Batterham, NMR Spectra of Simple Heterocycles, John Wiley & Sons, Inc., New York, 1973.
8. Ether 11 was also synthesized[5] independently from 2-acetylpyrrol-1-yl potassium and chloromethyl methyl ether and had $n_D^{24.5}$=1.5268; semicarbazone: m.p. 194-196° (dec.). Photolysis of 11 in methanol under the same conditions gave 2-acetyl-1-methylpyrrole, which itself is photostable.
9. Data derived from mass spectral analysis, using the following peaks: m/e 121-124 (compound 2); m/e 230-232 (compound 5); m/e 45-47 and m/e 153-155 (compound 11, average values shown, individual results differed not more than 4%). Total %H determined by NMR differed not more than 4% from the mass spectral results.
10. J. M. Patterson and L. T. Burka, Tetrahedron Letters, 2215 (1969).
11. M. Somei and M. Natsume, Tetrahedron Letters, 2451 (1973).

(Received in USA 20 October 1978)