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THE STRUCTURE OF THE PRODUCT OF OXIDATION OF PYRROLE $C_8H_{10}N_2O$

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Abstract—From the experimental results and with the aid of IR, UV and NMR techniques it is shown that structure of 5-(2-pyrrolyl)-2-pyrrolidinone (III) must be attributed to the product of oxidation of pyrrole, commonly known as oxo-bipyrrole (I, II).

ANGELI observed for the first time that pyrrole, by oxidation at room temperature in a solution of acetic acid with hydrogen peroxide in smaller amounts than those used in the preparation of pyrrole blacks, yielded a simple product of the formula $C_8H_{10}N_2O$ (m.p. 136°).[1]

The study of the structure of this product always aroused particular interest since it was considered the simplest compound of oxidation of pyrrole, intermediate in the formation of the corresponding blacks.[2]

According to the chemical behaviour, Pieroni suggested the structure of 3-hydroxy-2-2'-bipyrrole $C_8H_8N_2O$[2] (I) or one of its tautomers, and then of 5-hydroxy-2-2'-bipyrrole (II)[3a,b] or one of its tautomers; the latter was generally accepted[4] and till now known as oxo-bipyrrole (OBP).

This hypothesis led to the formulation of the probable structures of pyrrole blacks[3a,b] and the formation of secondary or intermediate products of oxo-bipyrrole type[5] obtained in the preparation of pyrrole blacks was explained accordingly.

As a result of more recent researches on terpyrrole[6], bipyrroles[7a–e] and also of some experimental data concerning OBP, one of us (L. C.) put forward the hypothesis[8] that none of the proposed structures represents correctly the compound under discussion and that the so called OBP contains only one pyrrolic ring.

The experimental data reported by previous authors and those reported here by us, suggest in fact that the structure of 5-(2-pyrrolyl)-2-pyrrolidinone (III) must be attributed to the presumed oxo-bipyrrole.

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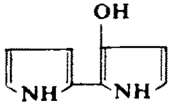
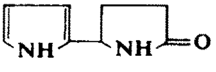
[1] A. Angeli and C. Lutri, *Gazz. Chim. Ital.* **50**, 128 (1920).
[2] A. Pieroni, *Rend. Accad. Lincei* **30**, II, 316 (1921).
[3a] A. Pieroni, *Rend. Accad. Lincei* **32**, II, 175 (1923).
[3b] A. Pieroni and A. Moggi, *Gazz. Chim. Ital.* **53**, 126 (1923).
[4] V. Grignard, *Traité de Chimie Organique* Vol. XIX, p. 159. Masson, Paris (1952).
[5] A. Quilico, *Gazz. Chim. Ital.* **62**, 822 (1932).
[6] L. Chierici and G. Serventi, *Gazz. Chim. Ital.* **90**, 23 (1960).
[7a] H. Rapoport and K. G. Holden, *J. Amer. Chem. Soc.* **84**, 635 (1962).
[7b] H. Rapoport and N. Castagnoli Jr., *Ibid.* **84**, 2178 (1962).
[7c] D. W. Fuhlhage and C. A. WanderWerf, *Ibid.* **80**, 6249 (1958).
[7d] R. Grigg, A. W. Johnson and J. W. F. Wasley, *J. Chem. Soc.* 359 (1963).
[7e] H. Rapoport and J. Bordner, *J. Org. Chem.* **29**, 2727 (1964).
[8] L. Chierici: *Communication at the Congress for the guidance and co-ordination of researches in Organic Chemistry.* Pisa (May, 1964.)


I

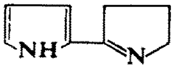
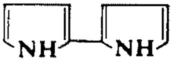

II


III

This structure (III), which explains better the existing experimental evidence, casts some doubts on the hypothesis that the product takes part to the formation of pyrrole blacks.

That OBP is a pyrrole derivative, had already been pointed out by Angeli[1] and by Pieroni[2] who noticed that this compound gives the reaction with sliver of firwood,[1] of Thormahlen[1] and of Erhlich,[2] with *p*-bromophenylazossicarbonamide yields the bis-α,α′-(*p*-bromophenylazo)-pyrrole[2] and after KOH hydrolysis and subsequent permanganic oxidation, probably yields the 2-pyrrolecarboxylic acid.[2,3a]

Table 1. Values of $\lambda_{max}(\varepsilon)$ of some substituted pyrroles

COMPOUND	SOLVENT	$\lambda_{max}(\varepsilon)$	REF.
	1N KOH–CH_3OH	287 (14,490) 278 (17,900)	7b
	MeOH	297 (8,200) (sh) 283 (16,000) 277 (17,300) 273 (16,700) (sh)	7a
	EtOH	218 (18,100)	
 (*)	EtOH	215 (11,000)	

* The spectrum remains unchanged in 0·1 N ethanol HCl.

The following evidence is reported to substantiate the structure III:

(1) UV absorption spectra in ethanol of OBP shows a single band at 215 mμ ($\varepsilon = 11{,}000$). As the examples reported in Table 1 show, this is typical for a non-conjugated pyrrolic ring.

(2a) OBP treated with iodine yields 5-[2(3,4,5-triiodopyrrolyl)]-2-pyrrolidinone.

(2b) 2-Pyrrolecarboxylic acid is obtained by permanganic alkaline oxidation, carried out on the product previously hydrolysed with alkali. As well as confirming the pyrrolic nature of OBP this emphasizes the fact that the compound contains a ring, different in nature from the pyrrolic ring, which can be easily hydrolysed.

(3) Chemical investigations[8] had already shown that the oxygen atom was not contained in a hydroxyl or an enolizable chetonic function: OBP does not react, for instance, with diazomethane.

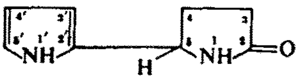
(4) The IR spectrum of OBP in KBr pellet shows characteristic absorptions due to NH- and CO-groups strongly associated. In $CHCl_3$ solution, the bands of associated NH- and CO-groups disappear slowly with increasing dilution; at a concentration

of about 0·01 mol/l the band at 1700 cm^{-1} of the free CO-group was observed which can be attributed to an amidic carbonyl-group. At the same dilution in the region of absorption of NH-groups a double band is observed: accordingly there is the possibility of the existence of both amidic NH-(3460 cm^{-1}) and pyrrolic NH-(3490 cm^{-1}) groups.

(5) Pyroglutamic acid is formed by ozonolysis of OBP in acetone–methanol: this indicates that a pyrrolidinone ring is present in the compound and that the bond between the latter and the pyrrolic ring involves the α,α' positions.

(6) The structure of 5-(2-pyrrolyl)-2-pyrrolidinone is confirmed by NMR[9] spectra. In Table 2 the chemical shifts in $CHCl_3$ are given.

TABLE 2



$H_{5'}$	$(H_{3'} + H_{4'})$	H_5[10]	$(H_3 + H_4)$[11]	$NH_{1'}$	NH_1
6·70	5·9–6·1	4·72	1·9–2·6	9·7	6·9

The lactamic form is also suggested for OBP at the concentration conditions (in $CDCl_3$ or in dimethylsulphoxide DMSO) in which the NMR spectra were measured, because both NH-groups do not exchange with trifluoroacetic acid (TFA).

In DMS solution, TFA immediately exchanges with water contained in the solvent: distinct signals at 8·2 and 10·8 due to NH-groups, and at 11·2 due to TFA could be clearly observed, even after the addition of TFA in excess. (10% in vol.)

Under such conditions an enolic hydroxyl group would exchange rapidly with TFA.

Also the observations made by Pieroni that OBP does not react with phenylhydrazine acetate,[2] yields succinimide in acetic solution by oxidation with hydrogen peroxide[2] and succinic acid by chromic oxidation, agree with the structure of 5-(2-pyrrolyl)-2-pyrrolidinone here proposed.

The relative inertia of OBP to give pyrrole blacks[3a] as well as its relative stability when subjected to oxidizing agents can now be understood: in fact OBP is obtained from a reaction involving peracetic acid lasting, even at room temperature, seven days.

The simultaneous formation of succinimide[12] in the preparation of pyrrole blacks with peracetic acid is now to be interpreted as due to a partial oxidation of 5-(2-pyrrolyl)-2-pyrrolidinone, formed in the process of oxidative polymerization of pyrrole and not by oxidation of pyrrole itself, as previously believed.

From the structure established, it must be considered improbable that OBP is an intermediate in the polymerization of pyrrole to yield pyrrole black; it is believed that

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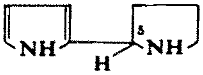
[9] NMR spectra were determined with a Varian A–60 spectrometer from 20 to 30% solutions. (Shifts are measured in ppm (δ)) from tetramethylsilane as an internal standard. A detailed analysis will be shortly published.

[10] The proton in C–5 in the compound  is at 4·25 ppm.[7b]

[11] In the 2-pyrrolidinone the protons in C–3 and C–4 show the same type of spectrum at 1·9–2·5 (Cat. Varian n.68).

[12] A. Quilico, *I Pigmenti neri animali e vegetali* p. 96. Tip. Fusi, Pavia (1937).

such process follows a different mechanism. It is more likely that 5-(2-pyrrolyl)-2-pyrrolidinone is the intermediate in the formation of trioxo-terpyrrole,[3b] which is also obtained in the oxidation of pyrrole with peracetic acid.

EXPERIMENTAL

5-(2-Pyrrolyl)-2-pyrrolidinone (oxo-bipyrrole)[1]

Pyrrole (37 g) in acetic acid (350 ml) was treated with 36% H_2O_2 (37 g). After standing 7 days (room temp), the mixture was neutralized with $CaCO_3$ and extracted with $CHCl_3$; after evaporation of the solvent, oxobipyrrole was obtained and crystallized from benzene as light yellow bright needles, m.p. 136° (with darkening). (Found: C, 63·99; H, 6·54; N, 18·61. Calc. for $C_8H_{10}N_2O$: C, 63·98; H, 6·71; N, 18·66% mol. wt: Found 159). The compound is not optically active.

Structure determination of 5-(2-pyrrolyl)-2-pyrrolidinone

(a) *Oxidation.* 5-(2-pyrrolyl)-2-pyrrolidinone (0·3 g) was dissolved in 1% KOH aq (200 ml) with gentle warming and heating prolonged for 10 min. After cooling, sat $KMnO_4$ aq was added dropwise with stirring until the colour of the oxidizing agent remained unchanged for 5 min. The excess of permanganate was destroyed, the mixture filtered and the filtrate acidified with HCl to pH 1-2, followed by continuous extraction with ether (6 hr).

The ethereal solution was dried over Na_2SO_4 and the residue dissolved in 2 ml ether–MeOH (9:1) treated with diazomethane. The 2-pyrrole-carboxylic acid methyl ester was determined by gas chromatography,[13] yield 15%. The low yield is certainly due (in part) to the instability of 2-pyrrole carboxylic acid to oxidizing agents.[14]

(b) *Ozonolysis.* Ozone was bubbled through a solution of 5-(2-pyrrolyl)-2-pyrrolidinone (2 g) in a mixture of acetone (20 ml) and MeOH (20 ml) at dry ice temp until absorption ceased. Then 1 g 5% PdC was added to the reaction mixture, and H_2 bubbled through the solution (2 hr) at dry ice temp.

The solution was then warmed to room temp and filtered; 30% H_2O_2 (6 ml) was added to the filtrate.

This mixture was allowed to stand overnight and then water (20 ml) was added. This solution was stored over Amberlite IR 45 ion exchange resin (6 g) in a closed container (24 hr) with stirring.

The resin was separated by filtration and eluted with dilute ammonia. The solution, after removal of excess ammonia by evaporation, was concentrated to 1 ml and analysed by paper chromatography and compared with a 1% solution of pyroglutamic acid ($R_f = 0{\cdot}60$) on Whatman No. 1 filter paper. The chromatograms were developed with a 12:3:5 mixture of *n*-butanol–acetic acid–water. A solution of blue bromophenol in EtOH made alkaline with a few drops of KOH was used as an indicator.

(c) *Iodination.* 5-(2-pyrrolyl)-2-pyrrolidinone (0·3 g) was dissolved in water (20 ml) with gentle heating and 50% KOH (2 ml) added to the solution. The resulting mixture was cooled to room temp and a sat. aqueous solution of I_2 (1·5 g) and KI (3 g) added dropwise with continuous stirring.

When approximately half the I_2 had been added, a flaky whitish compound precipitated. The addition of I_2 was stopped when the colouration became permanent. The precipitate was filtered off and crystallized from EtOH and decolourized with charcoal yielding white microcrystals m.p. 163° with decomposition and emission of I_2 vapour, yield: 78%. (Found: N, 5·47; I, 72·05. $C_8H_7J_3N_2O$ requires: N, 5·30; I, 72·13%).

Acknowledgment—We are indebted to Prof. A. Pieroni for his interest, advice and helpful discussions in the course of this investigation. Our thanks are also due to Dr. R. Mondelli of Institute of Chemistry of "Politecnico di Milano" for NMR spectra.

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[13] L. Chierici and G. Scapini, Ric. Sci. **34**, (II-A), 164 (1964).

[14] L. Chierici, unpublished work.