Studies in Organic Mass Spectrometry. VIII [1]. The Electron Impact Mass Spectra of 2,4-Substituted-3-diazo-5-phenylpyrroles

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The electron impact mass spectra (75 eV) of the β-diazopyrroles always show the molecular ions and undergo as the main fragmentation process the elimination of nitrogen followed by ring opening reactions leading to benzonitrile either as neutral or charged species. The peaks at 26 amu below the molecular ions, which are a general feature of these spectra, are due to the presence of the corresponding pyrroles which are formed by reductive reactions during the vaporization process of the samples.

Introduction.

The β-diazopyrroles were first synthesized over 80 years ago [2] and some derivatives had practical application in light-sensitive lithographic layers [3]. More recently their chemical reactivity under photolytic, thermolytic [4,5] and acid [6-8] conditions and their possible use as key intermediates for the synthesis of antineoplastic agents [9] have received considerable attention. In spite of this, there are no reports about their behaviour upon electron impact. In addition, few investigations have dealt with the mass spectral studies on other heterocyclic compounds [10,11], as they have been so far restricted to diazocarbonyl [10-28] and α-diazosulfone compounds [29]. Hence, it seemed of interest to report in this paper a study on the electron impact mass spectra of the 2,5-diaryl- and 2,4,5-triaryl-3-diazopyrroles 1-7.
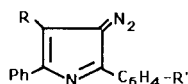
BLOCK 1 : Formulae 1-7

Comp.	1	2	3	4	5	6	7
R	Ph	Ph	Ph	Ph	Ph	H	H
R'	H	p-Me	p-OMe	o-OMe	m-OMe	H	p-Me

Results and Discussion.

The molecular ions of 1-7 are always observed (Table 1) and undergo, as the main fragmentation process, the elimination of a nitrogen molecule.

The elimination of nitrogen constitutes a characteristic feature of the mass spectra of the diazo-compounds [10-28] and it is generally due to the contribution of both thermal and electron impact induced processes. In our compounds, while the occurrence of the electron impact induced nitrogen loss is demonstrated by the presence of intense metastable peaks in both the 1st and 2nd field free

TABLE 1: characteristic common ions formed from 1-7 by E.I. processes

Comp :	1	2	3	4	5	6	7
Ions°	m/z (I%)	m/z (I%)	m/z (I%)	m/z (I%)	m/z (I%)	m/z (I%)	m/z (I%)
M	321 (32)	335 (13)	351 (38)	351 (70)	351 (36)	245 (24)	259 (31)
a	293 (40)	307 (28)	323 (40)	323 (67)	323 (49)	217 (86)	231 (68)
b	190 (100)	204 (100)	220 (100)	220 (12)#	220 (100)	114 (100)	128 (100)
b-Me	---	189 (34)	205 (31)	205 (10)	205 (17)	---	113 (4)
b-OMe	---	---	189 (6)	189 (39)	189 (29)	---	---
b-H	189 (98)	203 (20)	219 (2)	219 (28)	219 (5)	113 (19)	127 (23)

*m/z values and relative abundances (in parenthesis) referred to the base peak ; ° for ion assignement see text; #for this compound the base peak is at m/z 308

regions of the mass spectrometer, there is no evidence of any thermal contribution to the formation of ion **a** (Scheme 1). In fact, the [**a**]/[**M**⁺] abundance ratio is almost independent of the ionization chamber temperature in a

Scheme 1: Main E.I. induced fragmentations of 1-7
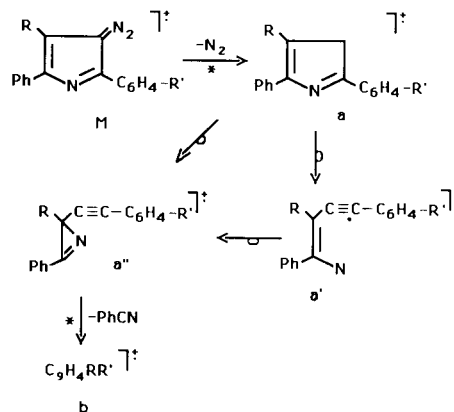
* metastable supported transition

range of 100°. The base peaks of the spectra of all the compounds, except for **4**, are due to the ions **b**, arising by

benzonitrile ejection as neutral from **a** (Scheme 1). A probable mechanism should involve the isomerization of **a** to **a″** either through ring-opening affording to the nitrene **a′** and subsequent heterocyclization, or by concerted **a → a″** rearrangement. The ion **b**, in turn, eliminates hydrogen or the substituent of the 2-phenyl ring (Table 1).

As it is known that α-diazoketones show mass spectral processes which parallel thermal, photochemical or catalytic reactions [15,18,22,25-30], a comparison between electron impact induced and photolytic or thermolytic decompositions of β-diazopyrroles should be of interest. Unfortunately, only the 2,5-diphenyl-3-diazopyrrole was investigated in this respect and the experiments were carried in solution phase [4,5]; so, the isolated products arise by reaction of the substrate with the solvent (solvent insertion and hydrogen abstraction). However, it is worthy of note that the proposed mechanism parallels the one reported for the formation of benzonitrile and 3-phenyl-2H-azirine derivatives which constitute the main products of the gas-phase pyrolysis of 3-phenyl-5-diazopyrazoles [31], the azirine derivatives being also formed from these latter by photolysis in cyclohexane. The base peak of **4** also arises from **a** by methyl loss; this different behaviour is attributable to a proximity effect between the methoxy group and the C-3 atom of the pyrrole ring, which should bring about the stable pyrrolo[2,3-b]benzofuran ion of m/z 308 (Scheme 2). Similarly, the abundant ion of m/z 322 (81% of the base peak), absent in the spectra of the isomeric compounds **3** and **5**, may be due to another *ortho* interaction involving the methoxy group (Scheme 2).

Scheme 2 : Characteristic ions of compound 4 formed by *ortho* interaction reactions.

a (m/z 323)

m/z 308 (100%)

m/z 322 (81%)
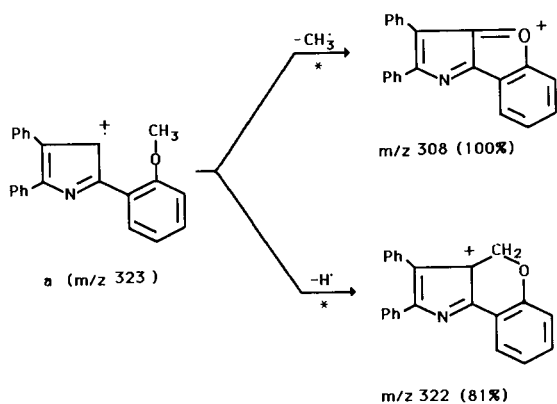
Furthermore, a general feature of the mass spectra of **1-7** which need some comments is the constant presence of ions with m/z values 26 amu below the parent ion also in freshly synthetized and purified samples.

High resolution measurements evidence that these peaks are due to ions which contain two more hydrogen

atoms than the molecular ions.

These ions of $[M - N_2 + 2H]^+$ have the same structure as the molecular ions of the corresponding pyrroles, as shown by identical lower mass peaks and, principally, overlapping efficiency ionization curves.

In order to verify the possibility of pre-existent pyrrole we analyzed by tlc the samples just purified by preparative tlc. The analysis revealed the presence of the corresponding pyrroles. The very high Rf differences between the parent pyrroles and diazopyrroles excludes a bad separation process; hence the only logical explanation is that the pyrroles are formed through a fast photochemical process involving nitrogen loss and hydrogen abstraction from the solvent [5]. In fact, when all the operation were carried in the dark, no traces of pyrroles were revealed by tlc.

However, even if in minor extent, peaks corresponding to ions of $[M - N_2 + 2H]^+$ were still present in the mass spectra of **1-7** compounds. Hence the photochemically induced pyrrole formation isn't the only source of such ions.

Peaks corresponding to ions of $[M - N_2 + 2H]^+$ were previously observed also in the electron impact mass spectra [10,11,15,18] of several cyclic diazocarbonyl compounds and the occurrence of reductive reactions on the metallic walls of the ion source was postulated to explain their formation [11,18].

However, the deuterium labeling experiments don't agree with this hypothesis for our compounds. In fact when the compound **1** (isolated in the dark) was introduced into the ion source saturated with a deuterium oxide flow, the peak of m/z 295 was shifted only one mass unit higher; in fact the peak of m/z 295, corresponding to ion of $[M - N_2 + 2H]^+$, and the peak of m/z 296, corresponding to ion of $[M - N_2 + {}^2H + H]^+$, are present in almost equal relative abundance.

The evidence of the incorporation of only one deuterium atom also for the sample **1** isolated in the dark, sug-

Schema 3 : Probable reactions of 1 on the probe tip surface.
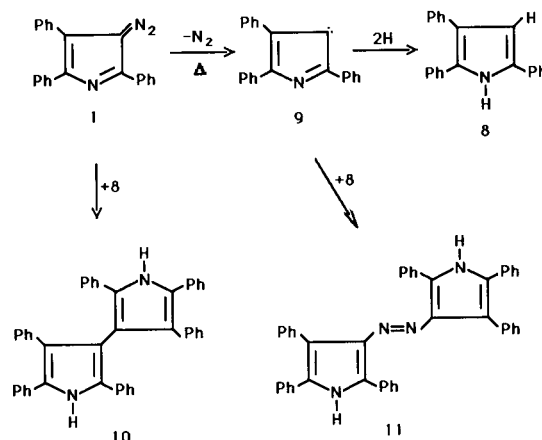
gests that the abstraction of two hydrogens following the nitrogen loss with formation of the parent triphenylpyrrole (**8**) occurs before the vaporization.

A logical explanation is that during the thermal vaporization process, the compound **1** (and consequently the other compounds **2-7**) undergoes nitrogen loss and the resulting carbene **9** becomes hydrogenated by abstraction of two hydrogen atoms from the surface of the glass probe tip (Scheme 3).

This hypothesis agrees with a recent study on the origin of the ions of $[M - N_2 + 2H]^+$ in the mass spectra of sulfonyl esters of diazonaphthalenones [27] and was confirmed by labeling experiments, treating the probe with a solution of sodium deuterium oxide (20%) in deuterium oxide. When the mass spectrum of compound **1** was performed under these conditions, the incorporation of two deuterium atoms was in evidence: in fact the peaks of $[M - N_2 + 2H]^+$ (m/z 295), $[M - N_2 + {}^2H + H]^+$ (m/z 296) and $[M - N_2 + 2\,{}^2H]^+$ (m/z 297) were observed in the 1:1:0.8 ratio.

Furthermore, the occurrence of reactions in the condensed phase before the volatilization process, was also evidenced by the presence of cross-linked reaction products. In fact when the mass spectrum of **1** (mp 142°) was run with a probe temperature of 180° the peak of m/z 295, corresponding to the molecular ion of triphenylpyrrole **8**, becomes dominant and, when the temperature of 240° was raised, consistent peaks of m/z 588 and of m/z 616, attributable to the molecular ions of the cross linked compounds **10** and **11** respectively (Scheme 3), were also observed.

Conclusions.

It has been evidenced as the main breakdown process of the compounds **1-7** consists in the elimination of nitrogen, which can be electron impact- or thermal- as well as photo-induced.

When such an elimination occurs in electron impact conditions, in the vacuum, it is followed by benzonitrile elimination as shown in the Scheme 1.

Thermal induced nitrogen loss occurs in the probe, before the vaporization of the samples, and the hydrogenation of the carbene species by interaction with the hydrogens of the probe surface leads to the corresponding pyrroles. At higher temperature pyrrole dimerization and copulation reaction between the parent diazopyrrole and the pyrrole formed in the probe were also observed.

Analogously, the photo-induced nitrogen elimination followed by hydrogen abstraction from the solvent is responsible of the formation of pyrrole during the chromatographic separation operating in the light.

Hence, it can be concluded that the abstraction of two hydrogen atoms by the species arising by nitrogen elimination from **1-7** is avoided only in monomolecular reactions, such in electron impact induced decompositions.

At this regard it is of interest to note that the mass spectra of sulfonyl esters of diazonaphthalenones obtained by chemical ionization (using methane as reagent gas) [27] or by fast atom bombardment (using hydrogen-rich matrices) [28] evidenced again a reduction process affording to $[M - N_2 + 2H]^+$ species.

EXPERIMENTAL

Low resolution mass spectra were measured on a Jeol JMS-01-SG-2 mass spectrometer, which consists of an EB (Mattauch-Herzog) geometry. In a typical experiment three scans were averaged. Ions were generated in the built-in electron impact ionization source operated at an ionization potential of 75 eV, and a total emission current of 100 μA. The accelerating voltage was 10 kV. The ionization chamber temperature was varied from 100° to 250°. Exact mass measurement were performed at 15,000 resolving power, using a photo-plate detection technique and perfluorokerosene as standard, and were run out to an accuracy of ± 10 ppm of the theoretical value. First field-free metastable ions were detected by the accelerating voltage scan technique. The samples were introduced to the source by direct inlet system, with a probe temperature of about 130°. The ir spectra (nujol) were recorded on a Perkin-Elmer 299 instrument. Melting points were detected in open glass capillary tube and are uncorrected.

General Procedure for β-Diazopyrroles **1-6**.

The β-diazopyrroles **1-6** were obtained from the corresponding β-nitrosopyrroles [32-35] by the described procedure [2,33,35]: zinc powder (0.5 g) was added to a glacial acetic acid (50 ml) solution containing the appropriate β-nitrosopyrrole and then the mixture was stirred for 30 minutes. The decolorized solution was neutralized by sodium carbonate and extracted with diethyl ether. After removal of the solvent under reduced pressure, the β-aminopyrroles (yellow powder) were crystallized from ethanol. Hence, an ice-cold solution in acetic acid of the appropriate β-aminopyrrole (0.01 mole) was added an equimolecular amount of sodium nitrite dissolved in the minimum volume of water. On neutralization with saturated aqueous sodium bicarbonate solution, the β-diazopyrroles **1-6** were precipitated as a brown powder; then they were crystallized from ethanol and, immediately before the insertion into the mass spectrometer, purified in the dark by preparative tlc on silica gel using methylene chloride as eluent.

2,3,5-Triphenyl-3-diazopyrrole (**1**).

The analytical data of this compound resulted identical to those previously reported [2,33].

2-*p*-Tolyl-4,5-diphenyl-3-diazopyrrole (**2**).

This compound was obtained as a brown powder (ethanol), mp 158-160°; ir: 2095 (N_2) cm^{-1}.
Anal. Calcd. for $C_{23}H_{17}N_3O$: C, 82.36; H, 5.11; N, 12.53. Found: C, 82.54; H, 5.26; N, 12.22.

2-(4-Methoxyphenyl)-4,5-diphenyl-3-diazopyrrole (**3**).

This compound was obtained as a brown powder (ethanol), mp 150-152°; ir: 2100 (N_2) cm^{-1}.
Anal. Calcd. for $C_{23}H_{17}N_3O$: C, 78.61; H, 4.88; N, 11.96. Found: C, 78.80; H, 5.01; N, 11.68.

2-(3-Methoxyphenyl)-4,5-diphenyl-3-diazopyrrole (**4**).

This compound was obtained as a brown powder (ethanol), mp 184-186°; ir: 2095 (N₂) cm⁻¹.

Anal. Calcd. for C₂₃H₁₇N₃O: C, 78.61; H, 4.88; N, 11.96. Found: C, 78.72; H, 4.99; N, 11.75.

2-(2-Methoxyphenyl)-4,5-diphenyl-3-diazopyrrole (**5**).

This compound was obtained as a brown powder (ethanol), mp 156-158°; ir: 2115 (N₂) cm⁻¹.

Anal. Calcd. for C₂₃H₁₇N₃O: C, 78.61; H, 4.88; N, 11.96. Found: C, 78.75; H, 5.03; N, 11.80.

2,5-Diphenyl-3-diazopyrrole (**6**).

The analytical data of this compound was identical to those previously reported [33,34].

Synthesis of 4-Diazo-2-phenyl-5-*p*-tolylpyrrole **7**.

4-Nitro-2-phenyl-5-*p*-tolylpyrrole-3-carboxylic acid (0.7 g), prepared according to the described procedure [36] and crystallized from benzene (mp 212-214° dec; ir: *ν* NH 3430, *ν* OH broad 3000-3100 cm⁻¹) was melted in a test tube and then kept at 225-230° for 15 minutes. After cooling the solid mass was dissolved in diethyl ether, washed with a solution of sodium bicarbonate, and dried (sodium sulfate). The solvent evaporation left to the 4-nitro-2-phenyl-5-*p*-tolylpyrrole as a yellow solid (ethanol), mp 174-176°; ir: 3300 (NH) cm⁻¹; ms: (m/z) 278 (M⁺). Palladium 10% on charcoal (100 mg) was added to a solution of 4-nitro-2-phenyl-5-*p*-tolylpyrrole (0.5 g) in 200 ml of ethanol. The mixture was hydrogenated in a Parr apparatus at 45-50 psi for 10 hours. After removal of the catalyst, the solution was evaporated to a small volume, to give the 4-amino-2-phenyl-5-*p*-tolylpyrrole as white crystals (ethanol), mp 194-196°; ir: 3100-3300 (NH) cm⁻¹; ms: (m/z) 248 (M⁺). Hence, the 4-diazo-2-phenyl-5-*p*-tolylpyrrole **7** was obtained by reacting with sodium nitrite, using the same procedure as for **1-6**. The elemental analysis of all the described products agrees with their molecular formulae (± 0.3%).

2-*p*-Tolyl-5-phenylpyrrole **7**.

This compound was obtained as a brown powder (ethanol), mp 115-117°; ir: 2090 (N₂) cm⁻¹.

Anal. Calcd. for C₁₇H₁₃N₃: C, 78.74; H, 5.05; N, 16.21. Found: C, 78.94; H, 5.05; N, 15.99.

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