E. I. INDUCED FRAGMENTATION OF SOME ALIPHATIC BI- AND TRICYCLOIMIDES

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Abstract - The mass spectrometric behaviour of two 3-azabicyclo[3.3.0]-1-octene-2,4-diones, 3-aza-6,8-dicarboxybicyclo[3.3.0]octane-2,4-dione, three endo-bicyclo[2.2.1]heptene-2,3-dicarboximides, endo-bicyclo[2.2.1]heptane-2,3-dicarboximide and spiro[bicyclo[2.2.1]hept-2,3-ene-2,3'-pirrolidin-2',5'-dione] is discussed in detail with the aid of exact mass measurements and E, B linked scans for metastable data collection. No general pattern was possible to propose, being the E. I. induced fragmentations strongly affected by structural differences and substituent effects.

INTRODUCTION

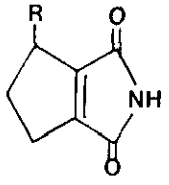
The first paper concerning the mass spectrometric behaviour of cyclic imides was published in 1965[1]: the fragmentation pattern of n-propyl and n-butylsuccinimides were discussed in detail with the aid of exact mass measurements and deuterium labelling experiments; the most abundant fragments were proved to involve a double hydrogen transfer from the alkyl chain.

In these fifteen years many other papers have appeared about cyclic imides mass spectrometry[2-9]. The most of these[2,3,4] are concerning the CO_2 loss mechanism, due to the E. I. induced imide-isoimide interconversion, observed for maleimide, N-methylmaleimide[2], N-phenylisomaleimide[3], N-phenylphthalimide, 4-phthalimidobiphenyl and 2-phthalimidobiphenyl[4]. I. E. and A. E. measurements and metastable intensities suggested that the CO_2 loss does not proceed through the ground state of the corresponding isoimide and the possibility of an electronically excited state mechanism was discussed[2].

No example of this CO_2 loss has been observed in the mass spectra of a large variety of imides[3] which lack the α,β unsaturated bond, also when the imidic system is connected to a rigid alicyclic system.

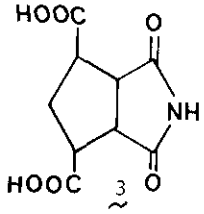
More recent papers, regarding the mass spectrometric behaviour of a large number of maleimides, isomaleimides, bis-maleimides, bis-isomaleimides[5], N-substituted cyclohexene-1,2-dicarboximides[6], substituted succinimides[7] and phthaloylamino-acids[8], confirm the previously reported general results. The fragmentation pattern of Maleimycin[10], a bicyclic maleimide antibiotic, follows the above considerations, but it shows an unusual primary NH_3 loss, never observed in the E. I. mass spectrometry of cyclic imides.

In the present paper we discuss in detail the mass spectrometric behaviour of 3-azabicyclo[3.3.0]-1-octene-2,4-dione (1), 3-aza-6-bromo-bicyclo[3.3.0]-1-octene-2,4-dione (2), 3-aza-6,8-dicarboxybicyclo[3.3.0]octane-2,4-dione (3), endo-bicyclo-[2.2.1]heptane-2,3-dicarboximide (4), endo-bicyclo[2.2.1]-5-heptene-2,3-dicarboximide (5), 2-methyl-endo-bicyclo[2.2.1]-5-heptene-2,3-dicarboximide (6), endo-bicyclo-[2.2.1]-2-heptene-2,3-dicarboximide (7), and spiro[bicyclo[2.2.1]hept-2,3-ene-2,3'-pirrolidin-2',5'-dione] (8), whose mass spectra are reported in figures 1 to 8, with the aid of exact mass measurements and linked scans[11] for metastable ions data collection.



1: R = H

2: R = Br



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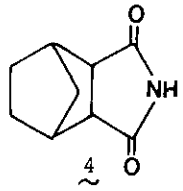

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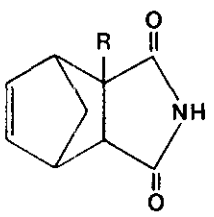
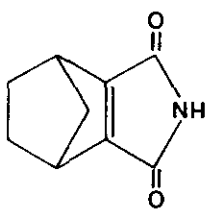
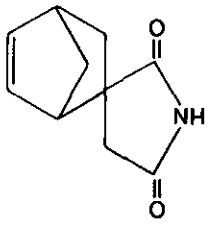






5: R = H

6: R = CH_3

7

8

EXPERIMENTAL

The mass spectra were obtained with an Hitachi RMU-6D single focusing instrument operating at 70 eV (80 μA). Samples were introduced directly into the ion source, heated at 150-200 °C. Metastable transitions were detected with E/B and E/B^2 linked scans[11] on a Varian MAT 112 S instrument. Exact mass measurements were performed with the peak matching technique at 6000 resolving power (10% valley definition). For compounds 1, 4, 5 and 7 exact masses of all the ionic species were measured with an AEI MS 902S mass spectrometer operating at 10000 resolving power (10% valley definition) connected with a DS 30 data acquisition system.

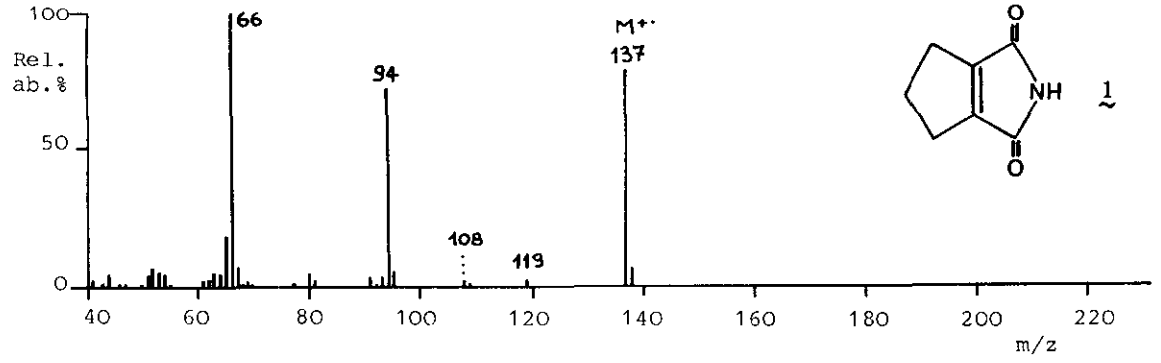


FIG. 1: Mass spectrum of compound 1

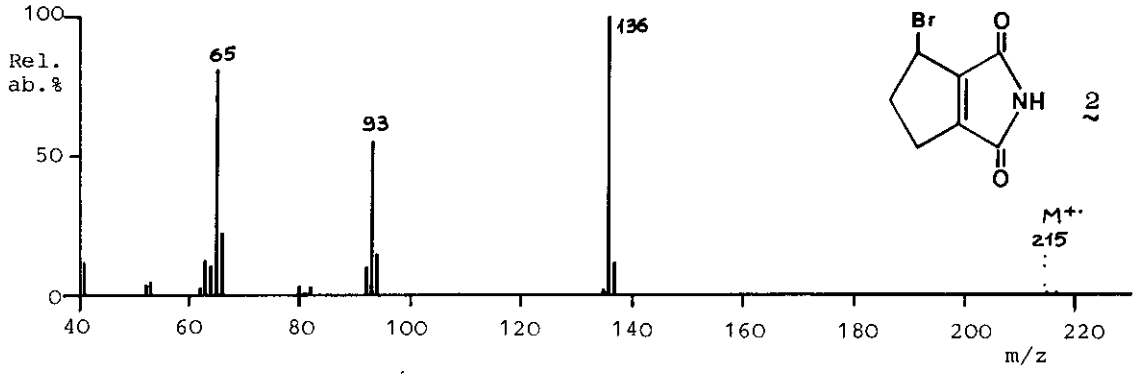


FIG. 2: Mass spectrum of compound 2

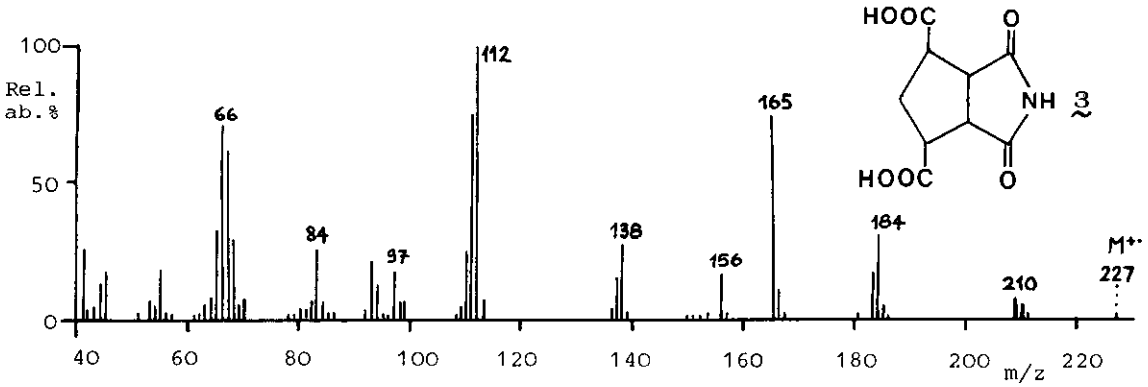


FIG. 3: Mass spectrum of compound 3

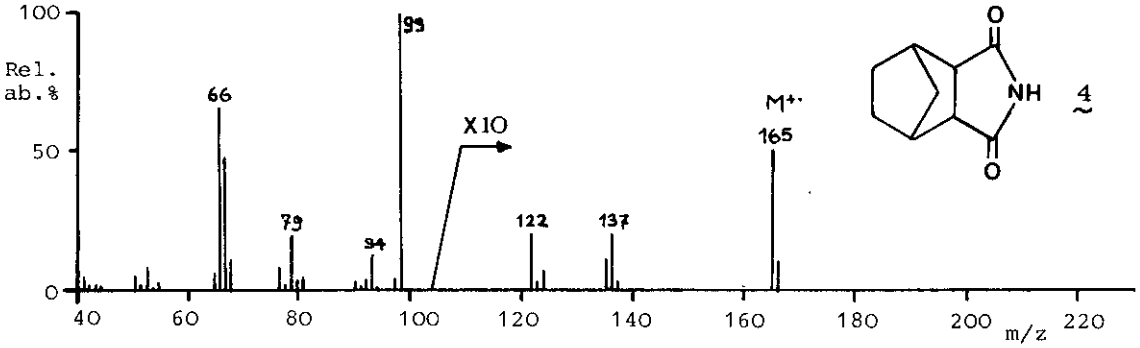


FIG. 4: Mass spectrum of compound 4

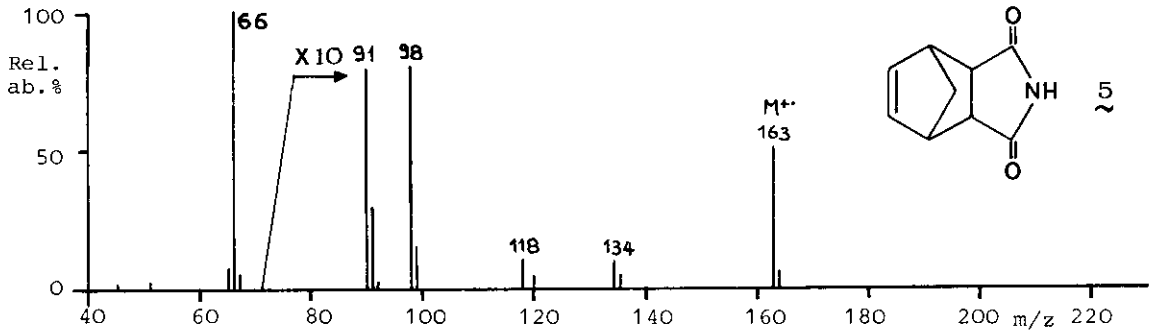


FIG. 5: Mass spectrum of compound 5

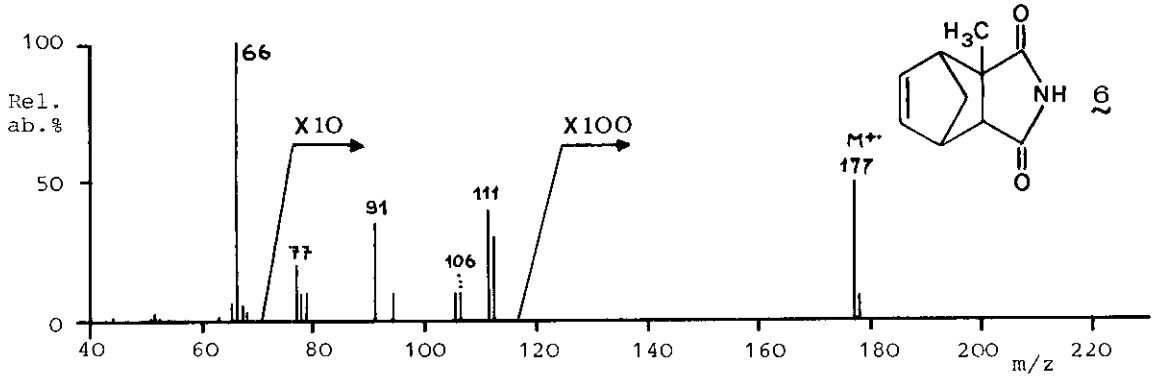


FIG. 6: Mass spectrum of compound 6

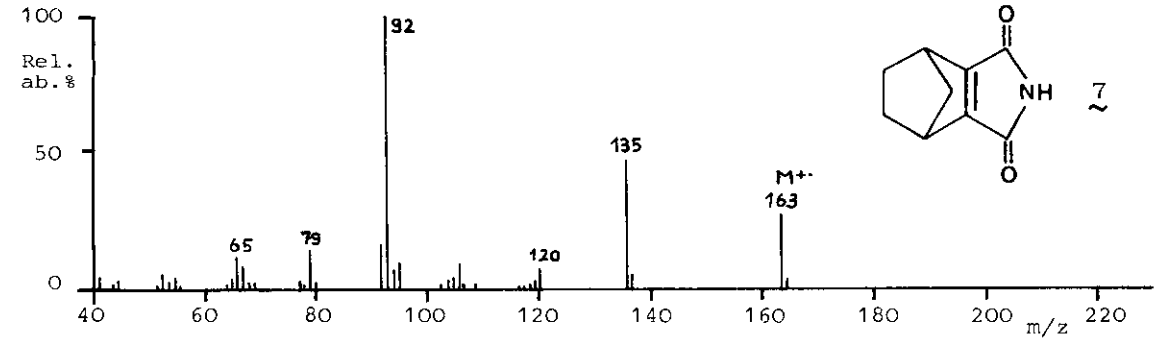


FIG. 7: Mass spectrum of compound 7

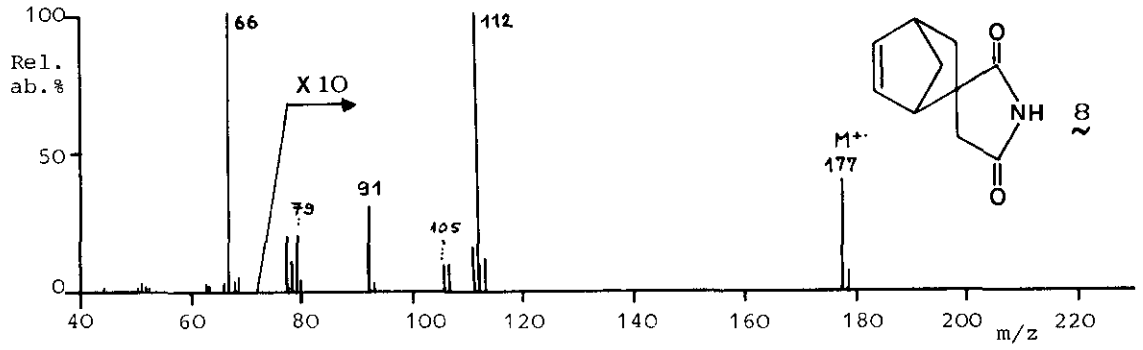


FIG. 8: Mass spectrum of compound 8

Compounds 1 and 2[12], 3[13], 4 and 5[14] were synthetized according to the literature; whereas 6, 7 and 8 were prepared as described below.

2-Methyl-endo-bicylo[2.2.1]-5-heptene-2,3-dicarboximide 6:

a 20% ammonium hydroxyde solution (15 ml) was added dropwise with stirring and cooling in an ice bath to 2-methyl-endo-bicyclo[2.2.1]-5-heptene-2,3-dicarboxy-anhydride[15]. The mixture was kept in refrigerator overnight and then the water was evaporated under reduced pressure. The solid residue was melted in an oil bath and maintained two hrs at 180°C. A crystallization from benzene gave the pure imide (m.p. 180°C) in a 80% yield.

NMR (90 MHz, $CDCl_3$): δ 1.50 (3H,s); 1.80 (2H, s); 2.85 (2H, m); 3.33 (1H, s); 6.25 (2H, m); 8.78 (1H, broad s).

IR (nujol): 1710, 1760 cm^{-1}.

Bicyclo[2.2.1]-2-heptene-2,3-dicarboximide 7:

to 1.0 g of bicyclo[2.2.1]-2-heptene-2,3-dicarboxyanhydride[16], 10 ml of a 32% ammonium hydroxyde solution were added with stirring and cooling. The mixture was stirred 10 minutes and then evaporated under reduced pressure. The residue was dissolved in the minimum amount of water and the solution acidified with hydrochloric acid. The separated solid was collected and, after drying in vacuo, was dissolved in 10 ml of trifluoroacetic anhydride and refluxed for 16 hrs. The trifluoroacetic anhydride was evaporated under reduced pressure and the residue

dissolved in ethylacetate. The solution was washed with a 5% $NaHCO_3$ solution with brine and dried over Na_2SO_4. After evaporation of the solvent and crystallization from ethylacetate-hexane, the pure imide, obtained in 80% yield, melted at 123°C.

NMR (90 MHz, $CDCl_3$): δ 1.10-1.65 (2H, m); 1.95 (4H, m); 3.40 (2H, s); 7.40 (1H, broad s).

IR (nujol) 1710, 1750 cm^{-1}.

Spiro[bicyclo[2.2.1]hept-2,3-ene-2,3'-pirrolidin-2',5'-dione] 8:
this compound was obtained in a 75% yield from spiro[bicyclo[2.2.1]hept-2,3--ene-2,3'-dihydro-2',5'-furandione][15] by the method used to make the imide 7. After cristallization from benzene, it melted at 156°C.

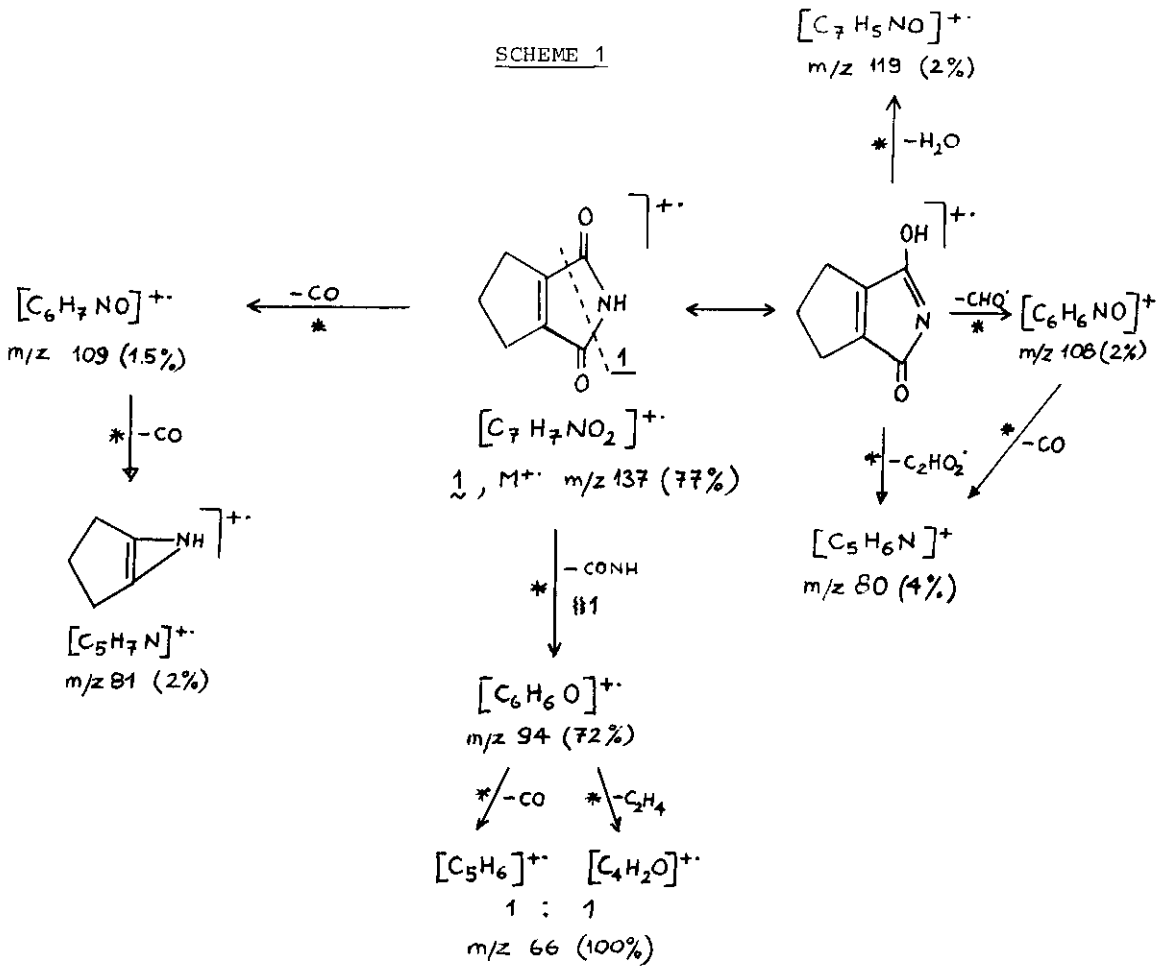
NMR (90 MHz, $CDCl_3$): δ 1.05-1.55 (2H, m); 2.27 (2H, m); 2.50 (2H, d J = 9Hz); 2.97 (2H, s); 6.20 (1H, m); 6.40 (1H, m); 9.10 (1H, broad s).

IR (nujol): 1690, 1770 cm^{-1}.

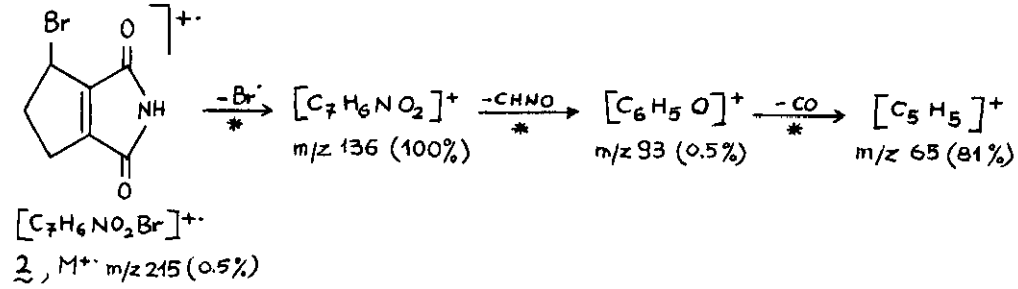
RESULTS AND DISCUSSION

The mass spectrum of compound 1 (figure 1) shows three intense peaks at m/z 137 ($[M]^{+\cdot}$), m/z 94 ($[M-CONH]^{+\cdot}$) and m/z 66 ($[C_5H_6]^{+\cdot}$ and $[C_4H_2O]^{+\cdot}$ in the ratio 1:1). By means of exact mass measurements and metastable ions data collection the following fragmentation pattern has been obtained (scheme 1). In this case the imide-isoimide interconversion[3] does not result to be a predominant process, being the $[M-CO_2]^{+\cdot}$ moiety, which may originate only from the isoimide structure of the molecule ion, particularly scarce (m/z 93 (0.5%)). The presence of a keto-imidic tautomerism, as indicated in scheme 1, is suggested by the primary losses of $CHO^{\cdot}$, H_2O and $C_2HO_2^{\cdot}$. The $[M-CONH]^{+\cdot}$ (m/z 94) species further decomposes with losses of CO and C_2H_4 giving rise to the mass spectrum base peak. An other minor fragmentation process leads to the $[C_6H_7NO]^{+}$ species, which losses CO (m/z 81(2%)). The presence of a Bromine atom in position 6 (compound 2) strongly modifies the fragmentation pattern. As it can be observed (figure 2 and scheme 2), a very

SCHEME 1



SCHEME 2



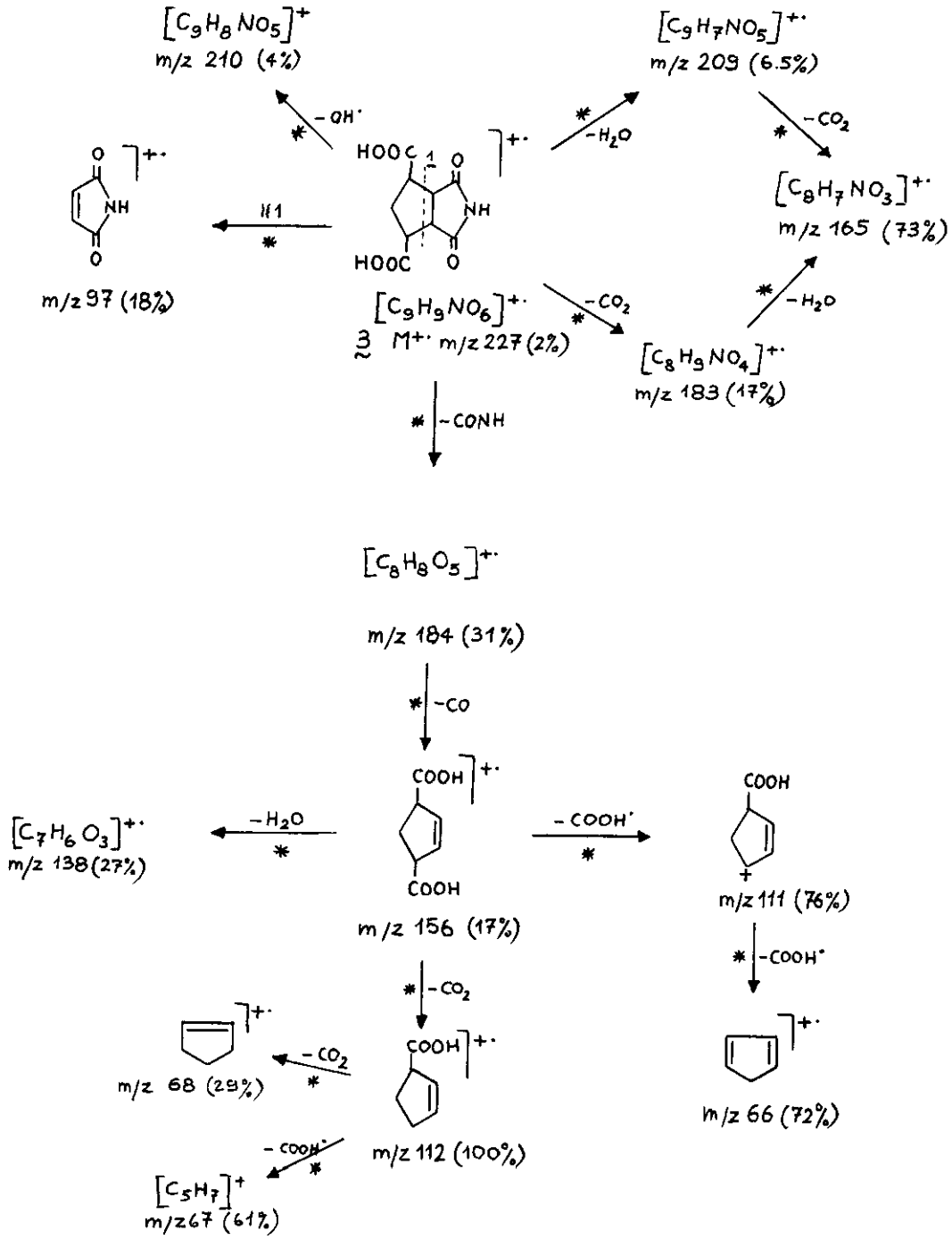
scarce molecular ion (m/z 215 (0.5%)) losses Br$^{\cdot}$ giving rise to the $[C_7H_6NO_2]^+$ moiety (100%), which further decomposes with subsequent losses of CONH and CO leading to $[C_6H_5O]^+$ and $[C_5H_5]^+$ ions respectively. No pathways due to imide-isoimide interconversion and/or to keto-imidic tautomerism have been in this case observed.

For compound 3 (figure 3) the presence of carboxylic groups in position 6 and 8 and the saturation of the 1-5 double bond lead to another different fragmentation pattern (scheme 3), being the most of the total ion current due to fragments originating from CO, CO_2 and COOH$^{\cdot}$ sequential losses. It is to observe the *presence of a maleimidic radical ion, completely absent* in the mass spectrum of 1, due to the lower I.P. of an imidic system with respect to carboxylic one[4] (for example, the I.P. value of benzoic acid is 9.73 eV, while the acetanilide one is 8.39 eV[17]). This behaviour follows the Stevenson's rule[18], which indicates as the more favorite fragmentation pathways those leading to ionic species with lower I.P. value.

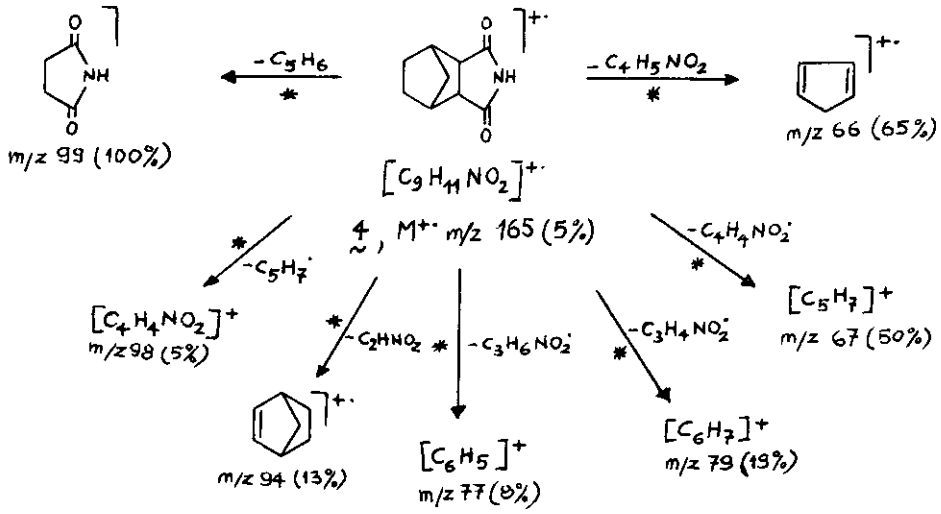
The mass spectrometric behaviour of compound 4 (see figure 4 and scheme 4) indicates as the more favourite processes those leading to hydrocarbon systems, which retain the most of the total ion current. The base peak is however due to succinimide radical ion (m/z 99), while the usual primary losses of CO, CONH, CO_2 and $CHO_2^{\cdot}$ are in this case strongly suppressed. The presence of peaks corresponding to $[C_6H_7]^+$ and $[C_6H_5]^+$ species indicates the occurrence of skeletal rearrangements.

For compound 5 (figure 5), whose mass spectrum has been already published[6], we have not found any OH$^{\cdot}$ loss, while the formation of norbornadiene was proved by linked scans to be a primary decomposition process. Then we give for compound 5 the fragmentation pattern reported in scheme 5. The base peak is due to a retro Diels-Alder type reaction on the molecular ion. The presence of a methyl group in position 2 (compound 6) does not affect the fragmentation pattern (see figure 6 and scheme 6). Again the base peak corresponds to the retro Diels-Alder fragment, while the maleimidic fragment is shifted, for the presence of the methyl group, at m/z 111-112. On the contrary,the presence of a single bond in

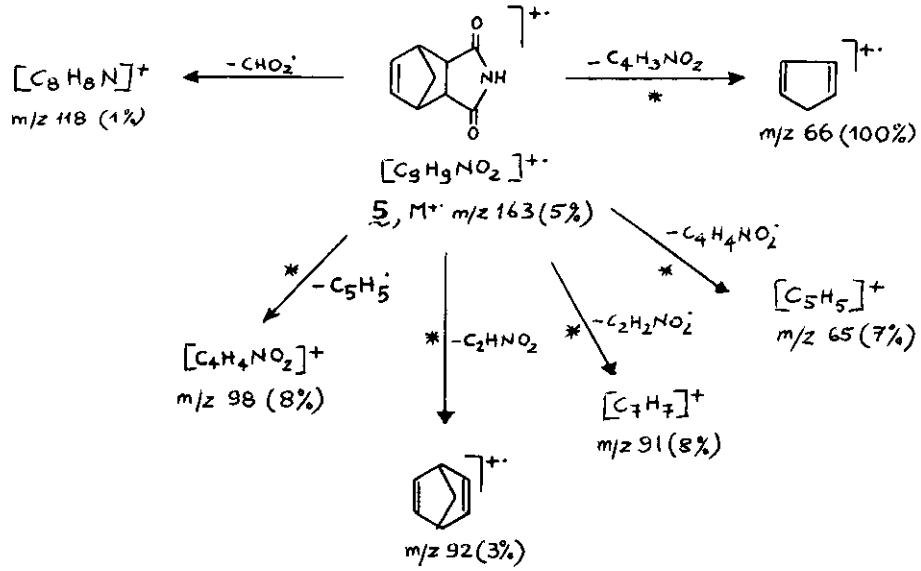
SCHEME 3


[C9H8NO5]+
m/z 210 (4%)
- OH·
[C9H7NO5]+·
m/z 209 (6.5%)
- H2O
- CO2
[C8H7NO3]+·
m/z 165 (73%)
HOOC
HOOC
NH
NH
O
O
O
O
O
O
m/z 97 (18%)
[C9H9NO6]+·
M+· m/z 227 (2%)
- CO2
- H2O
[C8H9NO4]+·
m/z 183 (17%)
- CONH
[C8H8O5]+·
m/z 184 (31%)
- CO
COOH
COOH
[C7H6O3]+·
m/z 138 (27%)
- H2O
- COOH·
COOH
m/z 111 (76%)
m/z 156 (17%)
- CO2
- CO2
m/z 68 (29%)
COOH
- COOH·
m/z 112 (100%)
m/z 66 (72%)
[C5H7]+
m/z 67 (61%)

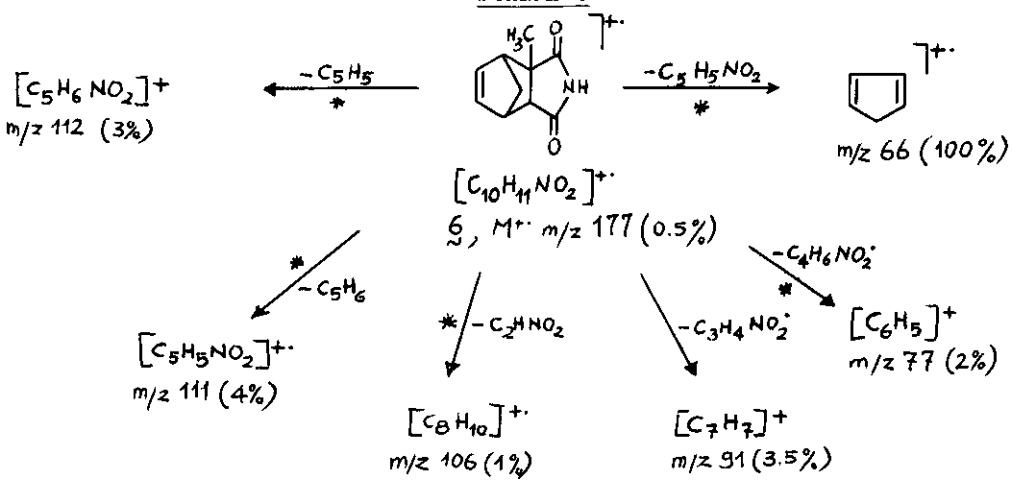
SCHEME 4



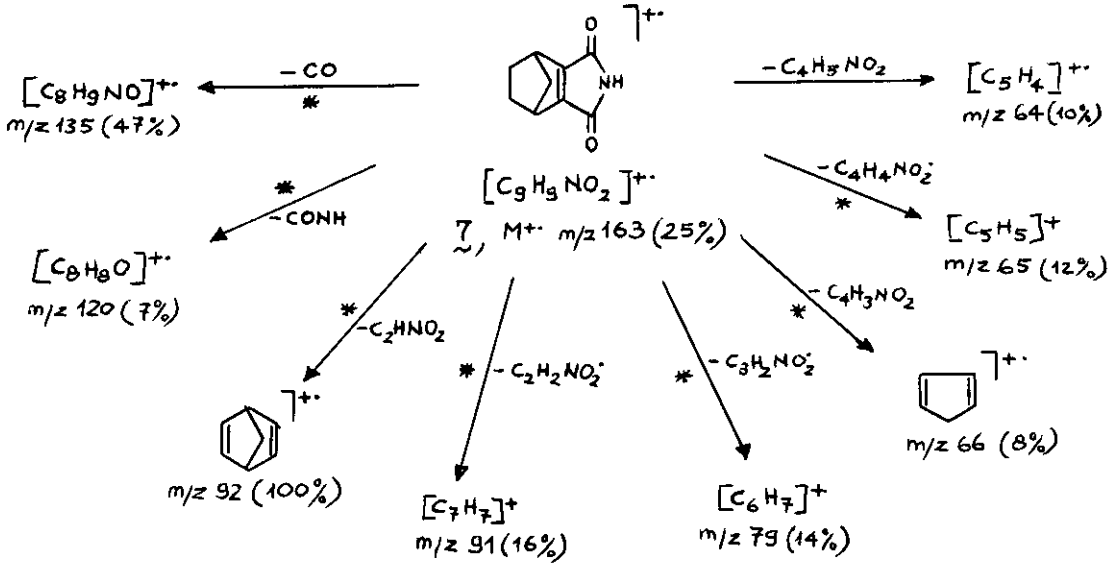
SCHEME 5



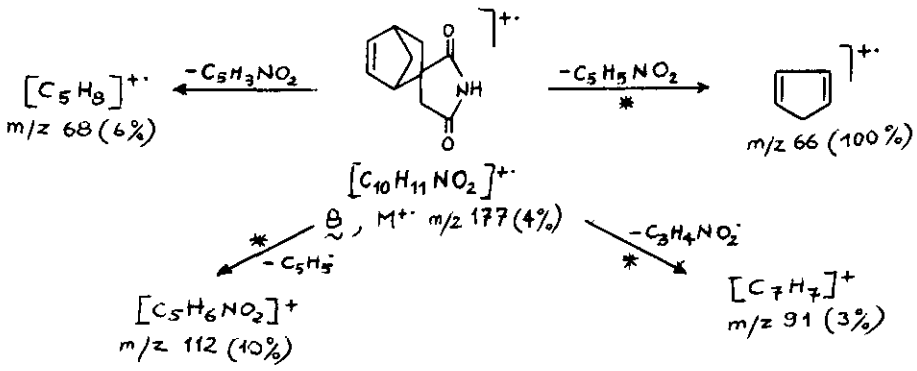
SCHEME 6



SCHEME 7



SCHEME 8



5-6 position introduces large differences. In the mass spectrum of compound 7 (figure 7), the base peak corresponds to norbornadiene radical ion, while maleimidic ions are completely absent. Primary losses of CO and CONH are more abundant than in compound 5 and the cyclopentadienyl ions become very scarce (scheme 7). Finally compound 8 (figure 8 and scheme 8), an isomeric compound of 6, exibits a fragmentation pattern very similar to that of 6, the only differences consisting in the relative abundance ratio between m/z 112 and 111 species.

ACKNOWLEDGEMENTS

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