MASS-SPECTRAL INVESTIGATION OF
4-ARYLOXAZOLES

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4-(p-Substituted)phenyloxazoles containing electron-donor and electron-acceptor substituents were synthesized and subjected to a mass-spectral study. On the basis of calculations of the free energies liberated in a number of metastable transitions, assumptions regarding the structures of some of the fragment ions are expressed.

The literature contains little data on the mass spectra of oxazole derivatives. Bowie and co-workers [1] have found* that the molecular ions of alkyl-, and aryl-, and aralkyloxazoles, as a rule, successively lose molecules of carbon monoxide and hydrogen. In order to study the effect of substituents in the benzene ring on the indicated type of fragmentation, we synthesized a series of p-substituted 4-phenyloxazoles (I-V, Table 1).

In a comparison of their mass spectra (Table 2) and the calculated values of the stability of the molecule with respect to electron impact (W_M) it was found that electron-donor substituents in the benzene ring increase the W_M value, while the introduction of nitro and bromo groups lowers W_M. As one should have expected, an increase in the length of the chain of the alkyl group in the benzene ring also leads to destabilization of the molecular ion. Consequently, the positive charge in the molecular ion of these compounds is localized primarily on the oxygen atom of the oxazole ring; this leads to a decrease in the electron density in the 4 position. The molecular ion undergoes disintegration in two directions: the usual pathway (observed in the mass spectra of all of the compounds) is apparently accompanied by isomerization of ion F_1 to ion F_2 with loss of a CO molecule (F_3) and subsequently of a HCN molecule, leading to hydrocarbon ions.

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*The mass spectra of three isomeric diaryloxazoles have also been described [2].

TABLE 1. 4-Aryloxazoles

Compound	R	mp, °C (Sublimation temp./mm)	Empirical formula	Found, %			Calc., %			UV spectrum (in ethanol)		Yield, %
				C	H	N	C	H	N	λ_{max}	lg ε	
I	CH₃	86—87 (76—79/20)	C₁₀H₉NO	75,4	5,7	8,8	75,4	5,7	8,8	250 274ᵃ	4,27 2,96	51
II	C₂H₅	58—59 (54—56/22)	C₁₁H₁₁NO	76,2	6,6	8,3	76,3	6,4	8,1	251 270ᵃ	4,21 3,17	47
III	Br	77—78ᵇ (69—72/21)	C₉H₆BrNOᶜ	48,2	2,7	—	48,2	2,7	—	254ᵃ 283ᵃ	4,47 3,21	42
IV	CH₃O	88—89 (79—83/21)	C₁₀H₉NO	68,5	5,2	8,4	68,6	5,2	8,0	256 286ᵃ	4,23 3,30	48
V	NO₂	177—180 (dec.) (139—143/20)	C₉H₆N₂O₃	56,6	3,4	14,5	56,8	3,2	14,7	218 312 354ᵃ	4,14 4,15 3,47	21

ᵃShoulder.
ᵇAccording to [6], this compound has mp 70°.
ᶜFound, %: Br 35.9. Calculated, %: Br 35.7.

TABLE 2. Mass Spectra of 4-Aryloxazoles I-V*

| Com-pound	Mass spectra (m/e values in percent of the maximum ion)
I	160 (8,8), 159 (100,0), 158 (20,5), 131 (28,8), 130 (8,8), 103 (27,4), 102 (24,7), 101 (6,4), 77 (17,8), 76 (21,9), 62 (7,7). $W_M = 33,83\%$
II	174 (8,6), 173 (100,0), 172 (6,9), 159 (8,8), 158 (100,0), 133 (16,7), 130 (16,7), 117 (12,2), 115 (12,2), 103 (10,1), 102 (7,8), 91 (9,0), 89 (7,9), 77 (26,7), 65 (8,4). $W_M = 25,61\%$
III	225 (61,6), 224 (5,5), 223 (65,6), 197 (16,4), 195 (17,8), 115 (5,8), 89 (6,3), 88 (100,0), 87 (14,4), 86 (7,7), 71 (5,5), 62 (27,4), 61 (19,2). $W_M = 33,72\%$
IV	176 (8,3), 175 (100,0), 160 (9,3), 147 (18,0), 133 (9,6), 132 (12,6), 120 (14,6), 105 (6,6), 91 (16,2), 90 (6,3), 89 (6,6), 77 (20,4), 76 (6,5). $W_M = 42,51\%$
V	191 (9,2), 190 (100,0), 160 (13,0), 144 (16,7), 132 (11,6), 116 (9,3), 89 (66,7), 88 (9,3), 87 (5,1), 77 (9,7), 63 (35,2), 62 (16,7). $W_M = 32,18\%$

* The ion peaks having intensities higher than 5% are presented.
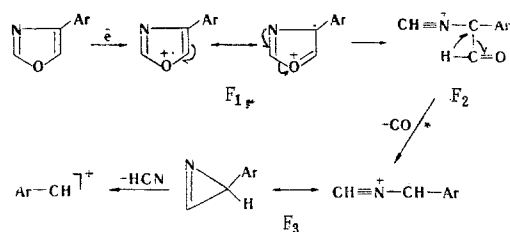
In those cases in which this process is especially favorable from the point of view of energy (I, III, and IV), it is accompanied by intense metastable transitions. In the case of IV, the peak of the metastable ion has a planar apex, and this made it possible to calculate, in accordance with the known relationship [3, 4], the energy (G) liberated during the loss of a CO particle by the molecular ion. According to our calculations, this energy is 0.38-0.39 eV; this indicates the high energic advantageousness of the process. The resulting $[M-CO]^+$ ion should be stabilized by resonance; this can be illustrated by a set of limiting structures:
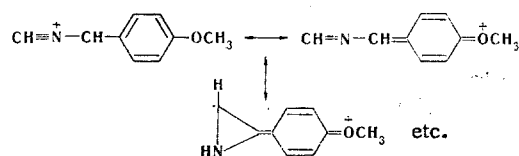
On the other hand, the pathway of dissociative ionization characteristic for a given substituent is always traced in the mass spectra. Thus, in the case of IV, an energically advantageous process involving the loss of a methyl group to give an F_4 ion, which apparently has a quinoid structure, is also observed. Ion F_4 then successively loses a CO molecule and a CO or HCN molecule.
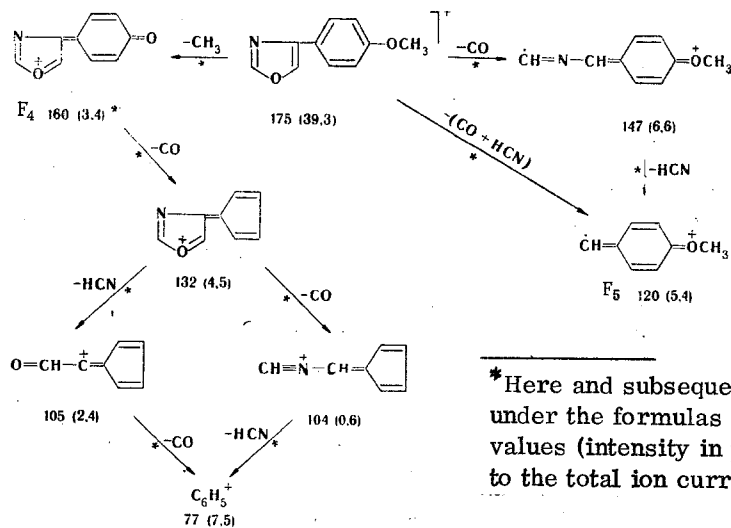
*Here and subsequently, the numbers under the formulas indicate the m/e values (intensity in percent relative to the total ion current).

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Ion F_5 is formed, on the one hand, by the loss of a HCN molecule by the $[M-CO]^+$ ion and, on the other, directly from the molecular ion by simultaneous ejection of CO and HCN. Both of these dissociative ionization reactions are accompanied by the liberation of considerable amounts of free energy (the metastable ions have a planar apex), but the first process is apparently energically more advantageous (T = 0.13 eV) than the second (T = 0.08 eV).

Compounds I and II have similar fragmentation character, and, in addition to the general disintegrative pathway presented in the scheme, peaks of F_6 ions formed by loss of hydrogen (I) or a methyl group (II) by the molecular ion are observed in the mass spectrum. This process is similar to the formation of ion F_4, and ion F_6 apparently has an identical structure in both the mass spectrum of I and II. This assertion is based on the fact that when the intensity ratios observed in each of the metastable ions characteristic for the $F_6 \rightarrow F_7$ process to the intensity of the ion with m/e 130 are compared, it is found that their values are of the same order $(2 \cdot 10^{-2}-4 \cdot 10^{-2})$. In addition, the values of the free energy liberated during the process, which were calculated on the basis of the width of the metastable peaks, have close and quite large values on the order of 0.31-0.32 eV. This indicates that the process is apparently accompanied by the formation of sufficiently stabilized rearranged ions, i.e., and oxazolyltropylium cation structure (F_6') is most likely for them.

The pathway of dissociative ionization indicated in the scheme above gives ions, the fraction of which in the total ion current is 42-52%.

In the case of IV, which contains a somewhat stronger electron-acceptor substituent (a strong $-I$ effect and a relatively weak $+M$ effect), the primary fragmentation of the oxazole ring is also retained, but both characteristic $[M-CO]^+$ and $[M-CO-HCN]^+$ ions

a R = H   159 (32.0)
b R = CH₃   173 (24.0)

F_6

130 (a 2.8) (b 4.0)   158 (a 6.6) (b 24.0) F_6^*

$C_8H_7^+$
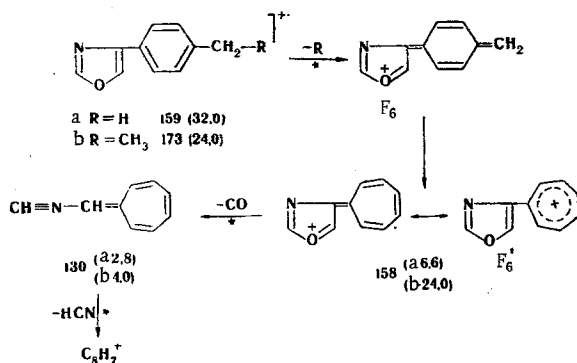
also lose bromine to give, respectively, ions with m/e 116 and 89, and the latter process is accompanied by a metastable transition.

However, in the case of an electron-acceptor substituent — a nitro group (V) — its loss by the molecular ion becomes more probable as compared with the characteristic disintegration of the oxazole ring, and the primary fragment ions are $[M-NO]^+$ and $[M-NO_2]^+$ ions. However, the subsequent fragmentation of the resulting fragments proceeds via the pathways already examined above.

144 (4.9)   190 (29.4) F_4' 160 (3.8)

116 (2.7)   162 (1.1)   (see Scheme 2)

$C_7H_5^+$ 89 (19.6) $C_5H_3^+$ 63 (10.0)
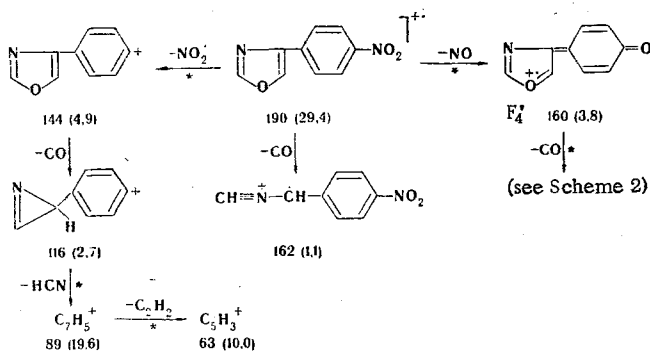
EXPERIMENTAL

The mass spectra were recorded with an MKh-1303 spectrometer with a modified system for recording with a loop oscillograph and introduction of the substance into the ionization region at an electron-

ionizing energy of 50 eV, an emission current of 150 μA, and an accelerating voltage of 2 kV at 20° (I, II), 25° (III), 30° (IV), and 100° (V). The UV spectra of ethanol solutions were recorded with a Cary spectrophotometer. The PMR spectra of CCl$_4$ (I-IV, with hexamethyldisiloxane as the internal standard) or acetone (V, HMDS as the external standard) solutions were recorded with a Varian T-60 spectrometer. The purity of the substances was monitored by chromatography in a loose thin layer of activity II aluminum oxide in benzene—cyclohexane—methanol systems (with different ratios of the components) and also from the disappearance of the absorption bands of the carbonyl group in the IR spectra.

The method in [5] (without the intermediate isolation of the phenacyl bromides) was used for the synthesis of I-V. An equimolar amount of bromine was added slowly with vigorous stirring at 50-70° to a mixture of the appropriate acetophenone and a four- to sixfold excess of formamide. The mixture was then heated and stirred at 110-125° for 6-8 h, after which it was poured into cold water. The aqueous mixture was made alkaline to pH ~10-11 with 2 N NaOH and extracted with ether. The extract was dried successively with anhydrous K$_2$CO$_3$ and fused KOH until it gave a negative Beilstein test for halogen. The ether was removed by distillation, and the residue was passed through a small layer of aluminum oxide in petroleum ether. The solvent was removed, and the residue was recrystallized from hexane or heptane or vacuum sublimed. In the case of V, the residue obtained in this manner contained a large amount of starting p-nitroacetophenone. The mass was treated with an alcohol solution of semicarbazide acetate (1:1), and the mixture was heated on a boiling-water bath for 1.5 h, after which it was applied to aluminum oxide and eluted with benzene. The product was recrystallized from petroleum ether—benzene. The yields and physical constants of the compounds obtained are presented in Table 1.

The structures of the compounds were also confirmed in all cases by the PMR spectra. In the case of I-IV, the signals of the protons of the oxazole ring had identical values — 7.7 ppm (8.1 ppm for III); the signals of these protons in the spectrum of V are found at 8.0 and 8.3 ppm.

LITERATURE CITED

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