Electron-Impact Induced Rearrangements in Isomeric Pyridine Aldoximes (1)

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The mass spectra of α -, β - and γ -pyridine aldoximes and the respective O-methyl ethers were studied. The mass spectral behaviour of α -pyridine aldoxime is characterized by the elimination of NO, while the molecular ion of the γ -isomer expels H_2 CN. In the case of the β -isomer the formation of the m/e 67 ion (C₄H₅N) in a concerted process is the main feature. In the α -pyridine aldoxime methyl ether, in sharp contrast to the hydroxy analog, the M-30 peak was found to be due to the elimination of CH₂O, the expulsion of NO being absent. The mechanism of the fragmentation reactions is discussed, the conclusion drawn being based on the high resolution measurements as well as on the spectra of the respective deuterioanalogs and on the metastable transitions.

Isomeric substituted benzaldoximes have been reported (3) to display remarkable mass spectral differences. It was found that OH migration is predominant in the *meta*-isomer, whereas the hydrogen transfer is preferred in the corresponding *para*-isomer (3). In the mass spectra of *meta*- and *para* chloro substituted benzaldoxime ethers (4) a similar preference for methoxyl migration in the former is observed.

In the isomeric pyridine aldoximes (Ia-IIIa), a considerable departure from the fragmentation pathways reported for the corresponding benzene derivatives (3) was observed. The ring nitrogen seems to be a decisive factor controlling the decomposition of the molecular ions of Ia-IIIa and of their O-methyl derivatives (IV-VI).

α-Pyridine Aldoxime (la).

The spectrum of la revealed the abundant peak at m/e 92 (Table I) arising from the elimination of NO accompanied by migration of the hydroxyl II atom to the charged fragment. This fact was confirmed by the deuterium labeling (Scheme I). The facile loss of NO from the α -aldoxime (Ia) is understandable on the basis of the tautomeric pyridone structure (5). It is to be noted that, while both α (Ia)- and γ -isomer (IIa) are prone to form pyridone tauto-

mers, it is conceivable that in the former (Ia) the nearby nitrogen accepts the II-atom of the hydroxyl function and thus promotes the elimination of NO. This hydrogen rearrangement in Ia seems to be energetically favorable as the m/e 92 ion was the most abundant fragment peak in the 15ev spectrum of Ia. In contrast, in the low energy mass spectrum of the γ -aldoxime IIa the m/e 92 was negligible (Table I). The latter fact suggests that in γ -isomer IIa the m/e 92 peak is due, probably, to the more complex high energy rearrangement process.

The methylation of the oxime la can be expected to stabilize the "oxime form" and thus to prevent the expulsion of the NO group. Indeed, as it was shown by exact mass measurements, in the methyl ether IV the M-30 peak (m/c 106) was due to the loss of the CH₂O and not the NO.

The further decomposition of the M-NO ion proceeded in a very peculiar way, i.e., the expulsion of the HCN is accompanied by the 90% loss of the hydrogen originating from the OH group of the molecular ion (Scheme 1). This is in strong contradiction with the reported (6,7) H-scrambling in the molecular ions of pyridine and α - and β -picolines. It can be assumed therefore that the elimination of HCN from the M-NO ion is preceded by a skeletal rearrangement producing an anilinium type ion a (Scheme 1). Indeed, in the case of aniline, the source of the hydrogen eliminated from its molecular ion during HCN loss was shown to be mainly the amino group (8).

γ-Pyridine Aldoxime (IIa).

The mass spectrum of IIa (Table I) displayed an interesting feature in the elimination of 28 mass units from the molecular ion. It was learned from the high resolution spectrum of IIa that more than 90% of the M-28 peak (m/e 94) is due to the M-H₂CN ion (b), whereas only 7% corresponds to the elimination of the CO from the molecular ion (Scheme 2).

The expulsion of H_2 CN proceeded in a concerted process $(M^{+} \to b)$ as confirmed by the appropriate metastable peak. An alternative pathway for the formation of this ion b is also available through the loss of a hydrogen atom, followed by the elimination of the HCN molecule. This fragmentation sequences $(M^{+} \to c \to b)$ was also confirmed by the metastable transitions.

It may be suggested that the H₂CN eliminated from the molecular ion of the aldoxime IIa was made up from the side chain HCN, the ring nitrogen not being involved in this reaction. This could be supported by energetic considerations. Indeed the activation energy for the reaction M⁺. → (M-HCN)⁺· for para-substituted benzaldoxime O-methyl ethers was reported to be of about 1.4-2.0eV (9) (appearance-ionization potential differences being used as rough guides to the activation energies) (10). In the case of the oxime methyl ether V the energetical requirements for the reaction M⁺· → (M-HCN)⁺· were found to be of the same order: about 1.35eV, and the same value was practically obtained for the elimination of H₂CN from the molecular ion of the oxime IIa (Z.V.I. Zaretskii, unpublished results.). In sharp contrast with these data the activation energy for the expulsion of HCN from the pyridine ring is more than twice as high: the AP-IP differences in pyridine and the isomeric picolines being of 3,5-4eV (Z.V.I. Zaretskii, unpublished results.) (7,11).

The fragmentation of the oxime IIa may include the tautomeric transformation of the molecular ion into the γ -pyridone form (Scheme 2). The hydroxyl hydrogen seems to play an important role in the suggested rearrangement. Indeed contrary to the oxime IIa, the methyl ether V, in which the tautomerism is prevented, displayed the intense elimination of HCN (Table I, m/e 109); the loss of H₂CN (m/e 108) was observed to a much lesser extent.

β-Pyridine Aldoxime (IIIa).

The β -isomer IIIa showed the intense formation of the m/e 67 ion. The fragment, formulated as the pyrrole ion-radical d (Scheme 3), arises both directly from the molecular ion, via a concerted process, and from the successive loss of HCN and CO. The last sequence was confirmed by the appropriate metastable peaks but in the case of the process ($M^+ \rightarrow d$) such a peak was absent from the spectrum. The suitable metastable transition was, however, recognized by the defocusing technique. In both cases the formation of the ion d was accompanied by the retention of the hydroxyl hydrogen in the charged fragment. The unusual formation of the pyrrole ion can be rationalized as shown in Scheme 3.

A possible driving force for this sequence could lie in the initial migration of the hydroxyl H atom to the ring nitrogen. Indeed the methyl ether VI, in which the above rearrangement is precluded, did not show the formation of the ions of this type.

One can assume that the loss of HCN from the aldoxime IIIa molecular ion proceeded through a five-membered transition state (12), and was accompanied by hydroxyl migration to the α -position of the ring. The M-HCN ion can be formulated as an α -pyridone ion-radical e, since this daughter ion showed the characteristic fragmentation patterns of α -pyridone itself (5). Indeed, as it was proven by

Table 1 (a)

Partial Mass Spectra of Oximes (Ia-Illa) and their Methyl Ethers (IV-VI)

	(la	(la)		(Ila)		(IIIa)			
m/e	70eV	15eV	70eV	15eV	70eV	15eV	(IV)	(V)	(VI)
50	11.5		30		23		12	24	18.5
51	23		59		41.5	0.5	32	69	51
52	15.5		14		12.5		19.5	23	14.5
5 4			8	0.5	1		0.5	2	1.5
63	5		10.5		10		5.5	9	9 8
64	3		2.5		7		5	9	8
65	51	1	14		4		2	5	2.5
66	5	-	9		5		5.5	18	8.5
67	$\overset{\circ}{2}$	0.5	16	1.5	24	6	1	4	1.5
76	4	0.0	7.5		9		4.5	6	6.5
77	3.5		13		40	l	6	15	25
78	19		28		16	0.5	65.5	72	83
79	25	4.5	13.5		12	1.5	100	25	24
92	26	5.5	8.5	0.5	1.5		1	4	1.5
93	3	0.0	13	1	4		1	17	3
94	ĭ		30	6	3		1	23	1.5
9 5	i		9.5		3.5	2	0.5	2	0.5
103	î		1.5		3		0.5	2	3.5
104	î		3.5	1	6	3	2.5	8	14
105	2	2	3		3.5	0.5	5.5	12	16.5
106		_			1.5	1	14	3	3
108							1	10	13
109							0.5	23	2 1
121	4.5	4	3	0.5	2	1	2	2	1
122	100	100	100	100	<u>100</u>	100			
123	10	9	9.5	9	9	$\frac{-10.5}{10.5}$			
135	10	,	7.0	,	•		0.5	4	0.5
136							27.5	100	100
137							2.5	10	10
197									

(a) Molecular peaks underlined.

exact mass measurements, the ion e decomposed further by the loss of CO to yield a pyrrole ion radical d (Table I), the ejection of HCN being absent. Moreover, in the 15eV mass spectrum of IIIa the ion d was the main fragment. These facts are in accordance with the behaviour of α -pyridone under electron bombardment: the latter eliminates exclusively CO, whereas its γ -isomer expels both CO and HCN (as the β -hydroxy pyridine does (5).

EXPERIMENTAL

The mass spectra were recorded at 70 and 15eV on an Atlas CH-4 Mass Spectrometer with TO-4 ion source. The samples were introduced as follows: the aldoximes la-IIIa via direct inlet system, at about 90°, the O-methyl ethers IV-VI - via double inlet system maintained at 80°.

The high resolution mass spectra were recorded using a Varian MAT 711 Mass Spectrometer in conjuction with a Spectrosystem 100 MS, at the resolving power of 10,000 and electron energy 70 eV. The elemental compositions of the principal fragment ions in the mass spectra of Ia-IIIa and IV were found to be as follows: m/e 121 ($C_6H_5N_2O$), 106 ($C_6H_6N_2$), 104 ($C_6H_4N_2$), 95 (C_5H_5NO),

94 ($C_5H_4N_0$; for IIa: 7% $C_5H_6N_2$), 92 (C_6H_6N ; for IIa: 5% $C_5H_4N_2$), 79 (C_5H_5N), 78 (C_5H_4N), 77 (C_5H_3N), 67 (C_4H_5N), 65 (C_5H_5), 52 (C_3H_2N/C_4H_4 1:1).

The measurements of metastable transitions were made using the above instrument as well as a MAT 311. Two different modes of metastable scanning were applied: the "normal defocusing technique" (NDT; MAT 711) and the direct analysis of the daughter ions (DADI; MAT 311) (13). The following metastable transitions were recognized using metastable peaks, when available, or the above techniques: $m/e 122 \rightarrow 95$ (IIIa), $95 \rightarrow 67$ (IIIa), $77 \rightarrow 51$ (Ia-IIIa), $104 \rightarrow 77$ (Ia-IIIa), $122 \rightarrow 121$ (IIIa, DADI; Ia, IIa), $122 \rightarrow 94$ (IIIa, $92 \rightarrow 65$ (Ia), $79 \rightarrow 52$ (Ia), $122 \rightarrow 92$ (Ia), $122 \rightarrow 79$ (IIIa, DADI), $122 \rightarrow 67$ (IIIa, DADI, NDT), $136 \rightarrow 135$ (V), $136 \rightarrow 109$ (V), $109 \rightarrow 108$ (V, VI), $136 \rightarrow 106$ (IV), $106 \rightarrow 79$ (IV, DADI), $78 \rightarrow 51$ (IV, V), $136 \rightarrow 79$ (IV, DADI), $105 \rightarrow 78$ (V), $93 \rightarrow 66$ (V), $135 \rightarrow 108$ (VI).

The nmr spectra were recorded in DMSO-d₆, at 25° on a Varian A-60 Spectrometer with tetramethylsilane as an internal standard. The pyridine aldoximes Ia-IIIa were commercially available (Fluka AG, pure grade). Their purity was checked by nmr and tlc.

O-Deuterio Analogs of the α -, β - and γ -Pyridine Aldoximes (Ib-IIIb).

The samples of the corresponding aldoxime Ia-IIIa and the deuterium oxide were introduced simultaneously through the high tem-

perature inlet system (90°), and the double inlet system of the Atlas CH-4 Mass Spectrometer, respectively. After 20 to 30 minutes, an equilibrium was attained and the spectrum was recorded. The final isotopic compositions were respectively: lb, 6% d_0 , 94% d_1 ; IIb, 9% d_0 , 91% d_1 ; IIIb, 8% d_0 , 92% d_1 . The same spectra were obtained with the samples of the lb-IIIb prepared independently by the heating of Ia-IIIa respectively in perdeuteriomethanol solution.

 α -, β - and γ -Pyridine Aldoxime Methyl Ethers (IV-VI).

The ethers IV-VI were prepared by direct interaction of the corresponding pyridine aldehyde and the water solution of the methoxyamine hydrochloride in the presence of sodium acetate, according to a modified procedure (14). The boiling points of the α , β and γ -pyridine aldoxime methyl ethers (IV-VI) were 108-110°, 174-175° and 182-184° respectively. All ethers gave satisfactory ir spectra (film); nmr (ppm): 1V 6.75 (α -CH=N), 3.98 (OCH₃); V 8.55 (γ -CH=N), 4.0 (OCH₃); VI 8.5 (β -CH=N), 3.97 (OCH₃). For the mass spectra of IV-VI see Table 1.

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