Mass Spectra of 3-Alkoxycarbonylmethylene-2(1H)-quinoxalinones and -2H-1, 4-benzoxazin-2-ones

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Mass spectra of 3-alkoxycarbonylmethylene-2(1H)-quinoxalinones (I-IV) and 3-alkoxycarbonylmethylene-2H-1, 4-benzoxazin-2-ones (VII and VIII) are examined. Most of these compounds are shown to exist in the enamine form with an internal hydrogen bonding in the crystalline, solution and gaseous states. Especially, the present mass spectral studies gave supports for the structure in the gas phase. 3-(1-Ethoxycarbonyl ethyl)-2(1H)-quinoxalinone(V) and 3-(2-ethoxycarbonyl ethyl)-2(1H)-quinoxalinone(VI), however, exist in the imine form, and mass spectral fragmentation pathways are understood as arising from the imine form of the molecular ion (M+). These fragmentations are confirmed by deuterium labeling experiments.

1. Introduction

Previous studies1,2 on 3-phenacyl-2(1H)-quinoxalinones and 3-phenacyl-2H-1, 4-benzoxazin-2-ones have shown that these compounds exist in the enamine form in crystalline (IR spectra for KBr disks) and solution (PMR spectra in DMSO-d6) states. The existence of the enamine form in the gaseous state was also confirmed by the mass spectrometry3.

We have, therefore, extended our study to 3-alkoxycarbonylmethylene-2(1H)-quinoxalinones (I-IV, X=NH) and 3-alkoxycarbonylmethylene-2H-1, 4-benzoxazin-2-ones (VII and VIII, X=O).

The existence of the enamine form for these compounds (Ia and VIIa) has been evidenced by the PMR spectra determined for DMSO-d6 solutions. The main subjects of this paper are the mass spectral studies characterizing these alkoxy derivatives of quinoxalinone (X=NH) and benzoxazinone (X=O), and more directly visualizing their existing form in the gas phase.

2. Result and Discussion

In the PMR spectrum of I, an olefin singlet appears at 5.66 ppm and two NH protons are observed at 11.15 and 11.85 ppm.
from TMS (δ-values). Similarly, in the spectrum of VII, an olefin singlet also appears at 6.05 ppm and the corresponding NH proton is observed at 10.81 ppm. These observations are consistent with the enamine forms (Ia and VIIa).

As an example, the mass spectrum of 3-methoxycarbonylmethylene-2(1H)-quinoxalinone (I) is given in Fig. 1, and the spectral data of I and the other analogs are summarized in Table 1. The fragmentation patterns deduced from the spectra are shown in Scheme 1. The asterisk under the arrow in Scheme 1 denotes that an appropriate metastable peak has been observed in the spectra.

The almost parallel relations among the prominent peaks are observed in the mass spectra of alkoxy carbonylmethylene derivatives of 2(1H)-quinoxalinone (I, X = NH) and 2H-1,4-benzoxazin-2-one (VII, X = O) as shown in Table 1.

Fragment ions derived by loss of stable neutral species (ROH or HCOOR) from the molecular ion (M⁺) are very prominent. Thus, the base peak of the spectra of quinoxalinone (X = NH) series is the ion.
Table 1. Mass spectral data of 3-alkoxycarbonylmethylene-2(1H)-quinoxalinones and 3-alkoxycarbonylmethylene-2H-1,4-benzoxazin-2-ones.

<table>
<thead>
<tr>
<th>Compound</th>
<th>m/e</th>
<th>M⁺</th>
<th>ion (a)</th>
<th>ion (b)</th>
<th>ion (c)</th>
<th>ion (d)</th>
<th>ion (e)</th>
<th>ion (f)</th>
<th>ion (g)</th>
<th>ion (h)</th>
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<td>158</td>
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<td>160</td>
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<td>172</td>
<td>144</td>
<td>201</td>
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<td>187</td>
<td>159</td>
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</table>

*These fragments (m/e 194) consist of the ion b (C₉H₇N₂⁺Cl⁻) and ion g (C₉H₇N₂O⁺Cl⁻) according to the isotopic cluster of chlorine.
Table 2. Mass spectral data of 3-(1-ethoxycarbonyl)ethy1)-2(1H)-quinoxalinone and 3-(2-ethoxycarbonyl)ethy1)-2(1H)-quinoxalinone.

<table>
<thead>
<tr>
<th>Compound Number</th>
<th>M⁺</th>
<th>Ion (a)</th>
<th>Ion (b)</th>
<th>Ion (c)</th>
<th>Ion (d)</th>
<th>Ion (e)</th>
<th>Ion (g)</th>
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<td>201</td>
<td>173</td>
<td>174</td>
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<td>144 131</td>
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<td>10.0 5.3</td>
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<tr>
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<td>m/e</td>
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<td>200</td>
<td>172</td>
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<td>145</td>
<td>144 131</td>
</tr>
<tr>
<td>Rel. int.</td>
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<td>23.0</td>
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<td>55.4</td>
<td>47.0</td>
<td>100.0</td>
<td>15.6</td>
<td>59.0</td>
<td>28.4 11.8</td>
</tr>
</tbody>
</table>

*a (m/e 186)*, which was probably due to loss of ROH from the molecular ion, while that in the benzoxazinone (X=O) series is the ion *b (m/e 159)*, which was due to loss of HCOOR from M⁺.

The loss of neutral species such as ROH and HCOOR from M⁺ have been widely known⁴) in the mass spectra of esters.

These fragmentations occurred in the spectra of all compounds in Table 1 and 2. On the other hand, scission of an alkoxy radical (-OR) from M⁺ resulted in an ion *d (m/e 187)*. Similarly, net loss of an alkoxy carbonyl radical (-COOR) from the side chain resulted in the production of an ion *e (m/e 159)*, which then lost CO to yield ion *f (m/e 131)*. It could be reasonable to interpret that the above fragmentation starts from the molecular ion existing in the enamine form.

Other prominent fragmentations of I IV involve a rearrangement giving rise to ion *g (m/e 160)*. These processes could be interpreted as illustrated in Scheme 1.

The successive loss of CO from the fragment *g (m/e 160)* resulted in the production of ion *h (m/e 132)*. Elimination of the whole side chain from M⁺ to give fragment ion *i (m/e 145)* does not take place in any appreciable amount, whereas the corresponding peaks for V and VI were the most prominent.

The mass spectra of 3-ethoxycarbonylmethylene-2(1H)-quinoxalinone(II), 3-ethoxycarbonylmethylene-6-methyl-2(1H)-quinoxalinone (III) and 3-ethoxycarbonylmethylene-6-chloro-2(1H)-quinoxalinone(IV) are shown in Table 1.

For comparison with compounds(I IV) and (VII and VIII), all of which exist in the chelated forms, the spectra of 3-(1-ethoxycarbonyl)ethy1)-2(1H)-quinoxalinone (V) and 3-(2-ethoxycarbonyl)ethy1)-2(1H)-quinoxalinone (VI) were examined.

In a striking contrast, these compounds (V and VI) exist in the imine form exclusively as shown by their PMR spectra⁶). Thus, for V, methyl doublet and methine qualttet were observed at 1.8 and 4.5 ppm, respectively. In addition to this, only one broad NH signal is observed in the region of 13 14 ppm.
Similarly, in the PMR spectrum of VI, a multiplet due to -CH₂-CH₂-group is observed in 2.9 ~ 3.4 ppm region. Furthermore, no indications of the olefin proton signal arising from the enamine form have been obtained. The observation of only one NH proton signal appeared at 12.5 ppm is also consistent with the imine structure (VIb).

In the mass spectra of V and VI, the fragment ion i (m/e 145) produced by the elimination of the whole side chain is pronounced giving a support for the imine structure. Moreover, the fragmentation pathway through a hydrogen rearrangement to the nitrogen atom becomes more apparent, and an intense peak g (m/e 174) is observed.

The mass spectral data of V and VI are shown in Table 2, and fragmentation processes are summarised in Scheme 2.

The mass spectra of these compounds have been further studied in detail with the use of deuterium-labeling techniques. Interestingly, in the compounds I ~ IV which existed in the enamine form with an intramolecular hydrogen bonding, two NH protons were exchanged by deuterium atoms. Thus, (M + 2)⁺ species appeared profoundly displacing their original molecular ion peaks. Not only the molecular ion displacement, but the shift of other ions similarly acquiring two atoms of deuterium occurred, as can be well-predicted

Scheme 2
from the ionic structures illustrated in the Scheme 1, ion \(d, e\) and \(f\), all possessing two NH groups. On the contrary, in the spectra of V and VI existing in the imine forms, only \((M+1)^+\) peak due to the single replacement with deuterium on NH group is observed. These observations suggest the difficulty of deuterium substitution in \(\text{CH-CH}_3\) or \(-\text{CH}_2-\text{CH}_2-\) group of V and VI. The migration of deuterium via the imine-enamine tautomerism onto side chain is, therefore, unlikely.

3. Conclusion

The main decomposition process is either loss of ROH or HCOOR from the molecular ion as usual in an ester fragmentation, but the other fragments arising from the enamine form are quite characteristic and similar to that of 3-phenacyl derivatives of 2(1H)-quinoxalinone and 2H-1,4-benzoxazin-2-one of our previous report\(^2\).

The compounds I~IV (X=NH) and VII and VIII (X=O) are all shown to exist in the enamine forms in gas phase where the mass spectra were measured. These forms are quite consistent with those in the crystalline and solution states as evidenced by IR and PMR spectra.

In contrast, the mass spectra of V and VI are quite different from those of I~IV and the spectra can be most easily rationalized by assuming that these compounds exist in the corresponding imine form.

Special emphasis may be laid on the observed phenomenon that the compounds I~IV, VII and VIII exist in the hydrogen bonded enamine forms and are firmly fixed in this forms, the compounds V and VI are, on the contrary, present in the imine forms and also fixed in this structure, i.e. the imine-enamine tautomerism can not take place in the gas phase.

4. Experimental

Mass spectra were recorded with a Hitachi RMS-4 mass spectrometer operated at an ionizing voltage of 75 eV and a sample temperature of 150°C using the direct inlet method. All compounds were of analytical purity and were prepared as described previously\(^1\).

References


Keywords

2(1H)-Quinoxalinone
2H-1,4-Benzoxazin-2-one
Mass spectra
Internal hydrogen bonding
Imine-Enamine Tautomerism
Fragmentation