

## Mass Spectrometry of Onium Compounds

### Part XIII.<sup>1</sup> Pyrolytic Behaviour of Dihydrothiazolo[3,2-a]pyridinium Carboxylates

REIDAR LIE and KJELL UNDHEIM

*Department of Chemistry, University of Oslo, Oslo 3, Norway*

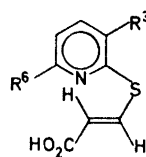
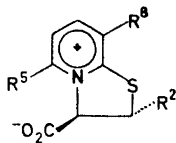
Dihydrothiazolo[3,2-a]pyridinium-3-carboxylates in the mass spectrometer have been shown to undergo decarboxylation and opening of the dihydrothiazolo ring to *N*-vinylpyrid-2-thiones prior to evaporation.

The spectra of *N*-vinylpyrid-2-thiones and analogous *S*-vinyl derivatives are very similar. The major primary fragmentation is rationalized by a common thiazolo[3,2-a]pyridinium intermediate. The corresponding intermediate from the 3-ethoxy homologues goes on to expel ethylene. Other ions are of low or medium intensities. In the 3-hydroxy series cleavage between the  $\alpha$ - and  $\beta$ -carbons in the side-chain results in another intermediate with the same mass to charge ratio. The signal intensities for these species were strong for the *S*-vinyl and weak for the *N*-vinyl analogues.

As a continuation of our studies on the behaviour of *N*-quaternary compounds in the mass spectrometer<sup>1</sup> we herein report on dihydrothiazolo[3,2-a]pyridinium-3-carboxylates and analogous *S*-vinyl pyridines.

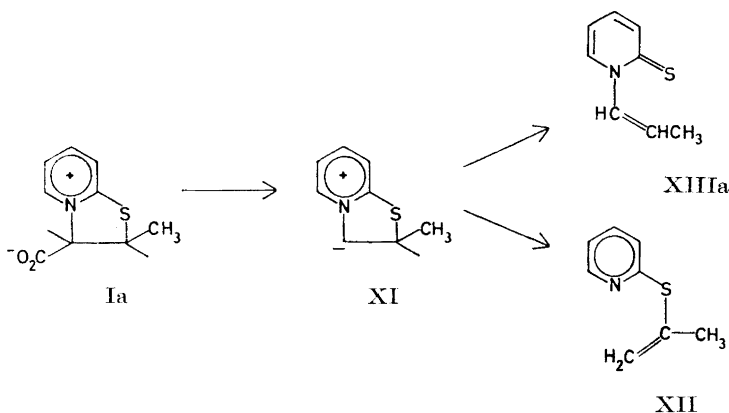
The compositions of the peaks discussed have been determined by high resolution. Metastable transitions, if not present in the ordinary spectrum, have been measured by the special defocusing technique<sup>2</sup> and these transitions are marked "m".

The spectra of the *N*-quaternary compounds (I-V) showed great similarities to the spectra of the *S*-vinyl derivatives (VI-X). Thus in each analogue pair such as Ib and VI the dominating fragmentation pathway goes through a common mass to charge intermediate which suggests similar structures in the gas phase. Also the molecular ion of I in the gas phase corresponds to a molecule which has been decarboxylated prior to evaporation. The zwitterion (I) cannot evaporate as such but will undergo a structural change to an uncharged molecule before evaporation. This the zwitterion can achieve



- I a  $R^2 = \text{CH}_3$ ,  $R^5 = R^6 = \text{H}$   
 b  $R^2 = \text{CO}_2\text{H}$ ,  $R^5 = R^6 = \text{H}$   
 II a  $R^2 = R^5 = \text{CH}_3$ ,  $R^6 = \text{H}$   
 b  $R^2 = \text{CO}_2\text{H}$ ,  $R^5 = \text{CH}_3$ ,  $R^6 = \text{H}$   
 III a  $R^2 = \text{CH}_3$ ,  $R^5 = \text{H}$ ,  $R^6 = \text{OH}$   
 b  $R^2 = \text{CO}_2\text{H}$ ,  $R^5 = \text{H}$ ,  $R^6 = \text{OH}$   
 IV a  $R^2 = R^5 = \text{CH}_3$ ,  $R^6 = \text{OH}$   
 b  $R^2 = \text{CO}_2\text{H}$ ,  $R^5 = \text{CH}_3$ ,  $R^6 = \text{OH}$   
 V a  $R^2 = R^5 = \text{CH}_3$ ,  $R^6 = \text{OC}_2\text{H}_5$   
 b  $R^2 = \text{CO}_2\text{H}$ ,  $R^5 = \text{CH}_3$ ,  $R^6 = \text{OC}_2\text{H}_5$
- VI  $R^5 = R^6 = \text{H}$   
 VII  $R^5 = \text{CH}_3$ ,  $R^6 = \text{H}$   
 VIII  $R^5 = \text{H}$ ,  $R^6 = \text{OH}$   
 IX  $R^5 = \text{CH}_3$ ,  $R^6 = \text{OH}$   
 X  $R^5 = \text{CH}_3$ ,  $R^6 = \text{OC}_2\text{H}_5$

by decarboxylation of the activated 3-carboxyl group followed by ring opening of XI either by breakage of the C-S or C-N bond.



Formation of the *S*-vinyl derivative (XII) involves a proton shift prior to ring opening. Direct formation of the *N*-vinyl structure therefore is more likely. The latter structure (XIIIa) was experimentally verified by subjecting Ia to preparative pyrolysis at 120°C/0.01 mmHg. The yellow liquid obtained had the same mass spectrum as that from Ia and its structure follows from its NMR spectrum recorded in TFA. The three methyl protons resonate as two quartets at 7.8 and 8.4  $\tau$  with a primary coupling constant of 7.0 cps and secondary coupling constants of  $J = 1.0$  cps and  $J = 1.5$  cps. A complex two-proton signal appeared in the 2.7–3.8  $\tau$  region with  $J = 14.0$  cps for the olefin protons in the major product. The other coupling constant was not immediately apparent. These data are only consistent with the *N*-vinyl structure and the major product has a *trans* configuration, the ratio between *trans* and *cis* olefin from integration of the spectrum being 3:1.

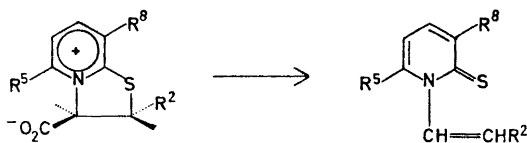
Preparative pyrolysis as above of the dicarboxy acid (Ib) gave mainly pyrid-2-thione. Pyrolysis in the mass spectrometer, however, follows a different course with formation of the *N*-vinyl acid. Its fragmentation pattern is very similar but not in all details identical with that of the *S*-vinyl isomer (VI). The latter could be distilled at 140°/7 mmHg and gave the true molecular ion in the mass spectrum.

The methyl homologue series (IIb and VII) gave the same type of spectra and the quaternary compounds (II) therefore undergo the same thermal transformations before evaporation.

The hydroxy derivatives (III and IV), as the tautomeric 3-carboxy-dihydrothiazolo[3,2-*a*]pyridinium-8-oxides, could evaporate as uncharged molecules after internal charge compensation which does not involve opening of the dihydrothiazolo ring.<sup>3-5</sup> Neither III nor the methyl homologue (IV), however, give the true molecular ion but a signal corresponding to the decarboxylated material with fragmentation pattern similar to the desoxy series (I and II). Therefore these molecules suffer decarboxylation and ring opening before evaporation.

In view of the above findings it is not surprising that the ethoxy derivatives (V) are also decarboxylated and transformed to *N*-vinyl analogues before evaporation.

Since the dihydrothiazolo[3,2-*a*]pyridinium derivatives (I–V) undergo ring-opening prior to evaporation the electron induced fragmentation is discussed in terms of the pyrolytically formed *N*-vinyl derivatives (XIII–XVII).

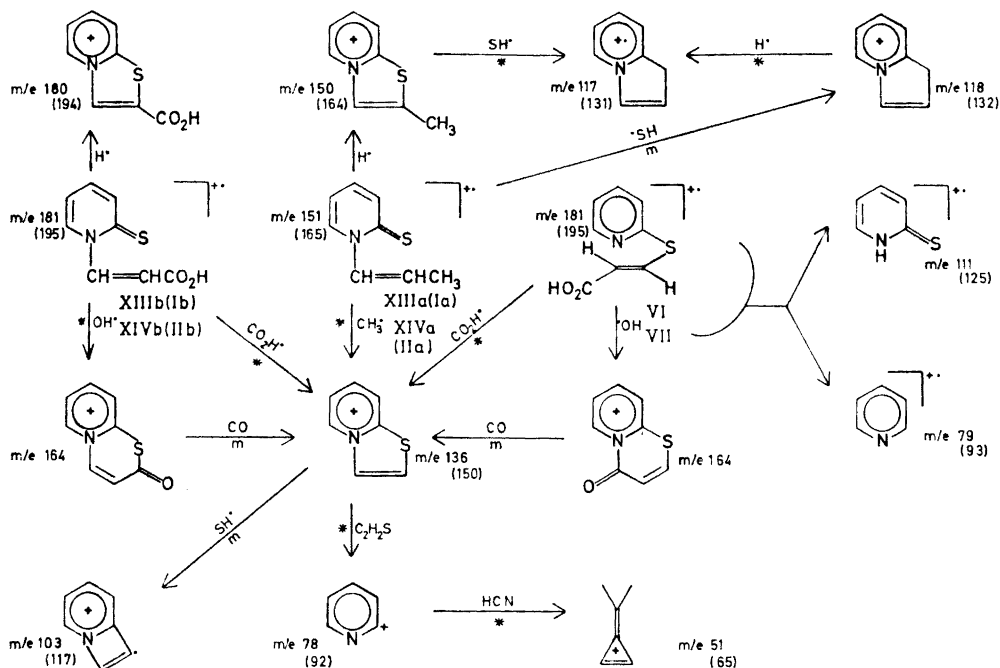


I–V

- XIII a  $R^2 = \text{CH}_3$ ,  $R^5 = R^8 = \text{H}$   
 b  $R^2 = \text{CO}_2\text{H}$ ,  $R^5 = R^8 = \text{H}$   
 XIV a  $R^2 = \text{CH}_3$ ,  $R^5 = \text{H}$ ,  $R^8 = \text{CH}_3$   
 b  $R^2 = \text{CO}_2\text{H}$ ,  $R^5 = \text{H}$ ,  $R^8 = \text{CH}_3$   
 XV a  $R^2 = \text{CH}_3$ ,  $R^5 = \text{OH}$ ,  $R^8 = \text{H}$   
 b  $R^2 = \text{CO}_2\text{H}$ ,  $R^5 = \text{OH}$ ,  $R^8 = \text{H}$   
 XVI a  $R^2 = \text{CH}_3$ ,  $R^5 = \text{OH}$ ,  $R^8 = \text{CH}_3$   
 b  $R^2 = \text{CO}_2\text{H}$ ,  $R^5 = \text{OH}$ ,  $R^8 = \text{CH}_3$   
 XVII a  $R^2 = \text{CH}_3$ ,  $R^5 = \text{OC}_2\text{H}_5$ ,  $R^8 = \text{CH}_3$   
 b  $R^2 = \text{CO}_2\text{H}$ ,  $R^5 = \text{OC}_2\text{H}_5$ ,  $R^8 = \text{CH}_3$

The spectra from the quaternary acids (I), which are evaporated as the *N*-vinyl derivatives (XIII), are very similar to the spectrum of the *S*-vinyl analogue (VI) (Fig. 3). The dominating pathway for all three compounds involves expulsion of a formyloxy (XIIIb and VI) or a methyl (XIIIa) radical to a common intermediate at  $m/e$  136 (Scheme 1). The stability of this fragment is such that it is the base peak in all the spectra and undergoes little further fragmentation. The highest intensities of the other ions are of the order 20–40 % of the base peak, usually in the lower region. An exception

is the  $\text{CO}_2$  peak at  $m/e$  44 in the spectra of the quaternary derivatives but this is formed by pyrolysis and therefore shows variable intensities. The  $\text{CO}_2$  peak is absent or practically absent in the spectra of the *S*-vinyl derivative which therefore is not pyrolyzed to any extent.



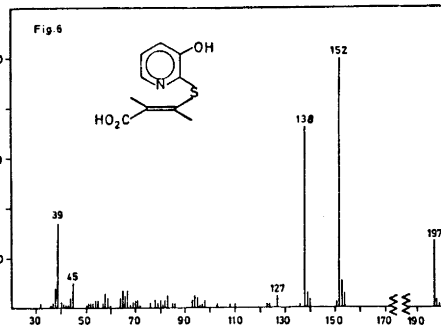
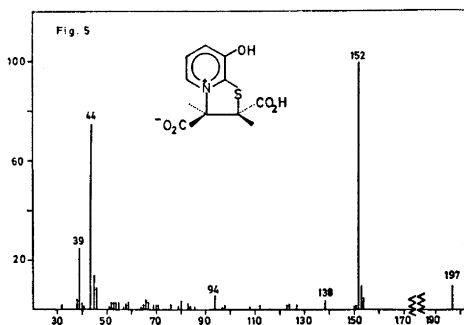
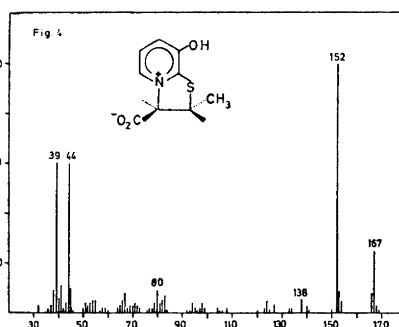
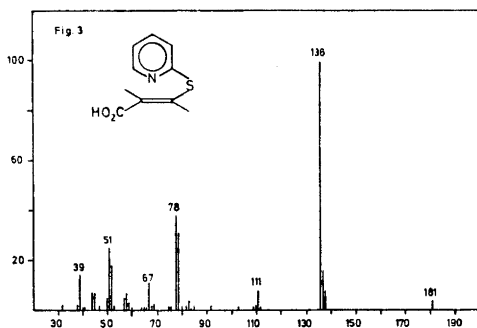
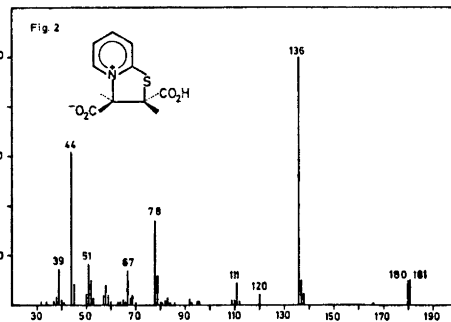
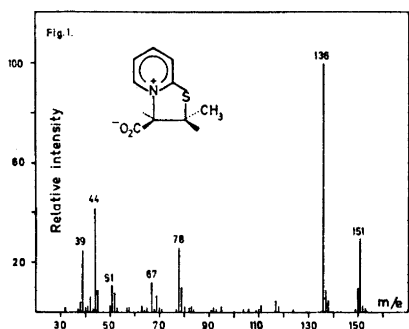
Scheme 1.

The representation which best explains the great stability of the common intermediate at  $m/e$  136 is thought to be a thiazolo[3,2-*a*]pyridinium cation. Its formation from the molecular ion is accompanied by a strong metastable in the ordinary spectrum. The formation of this ion can also take place in a two-step process from the carboxylic acid derivatives (XIIIb and VI) by hydroxyl radical expulsion followed by CO. The peak intensity from the intermediate ions at  $m/e$  164 is so low, however, that this is probably not an important pathway but does occur as demonstrated by the defocusing technique.

Hydrogen radical expulsion is an alternative route to thiazolo[3,2-*a*]pyridinium structures. This pathway is of no importance for the *S*-vinyl derivative (VI) (Fig. 3) but the isomeric *N*-vinyl acid (XIIIb) gives the  $[\text{M} - \text{H}]$  ions at  $m/e$  180 (Fig. 2). The relative intensity for the latter is about 10 % and the same as for the molecular ion. Due to low intensity and relatively high stability of the  $[\text{M} - \text{H}]$  cation further fragmentation of this ion is not easily detectable. A closer examination of the  $[\text{M} - \text{H}]$  species at  $m/e$  150 in

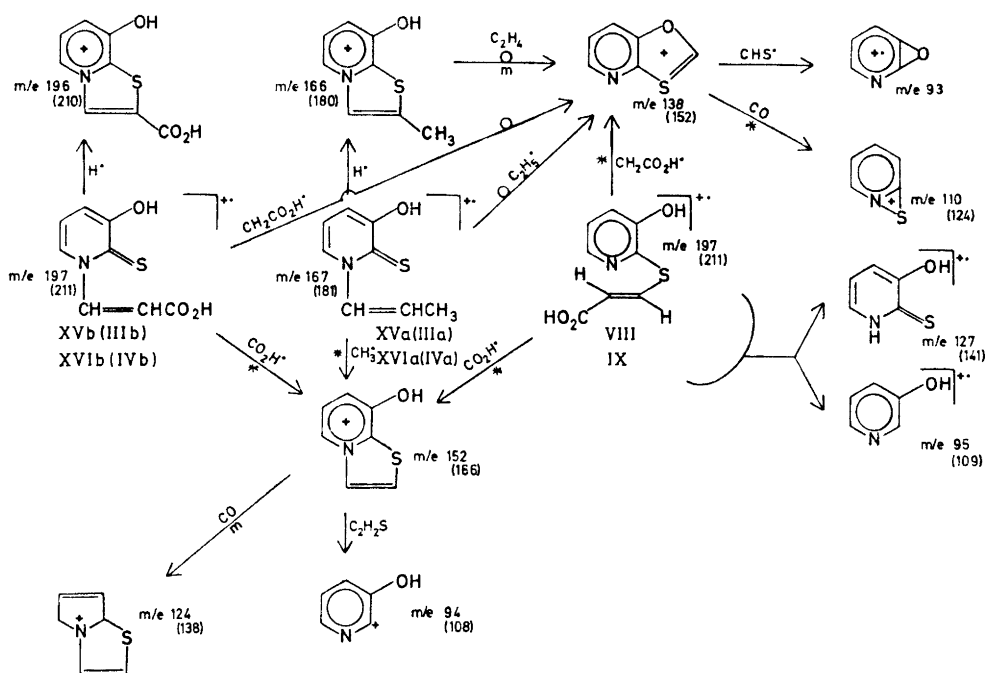
the spectrum of XIIIa (Fig. 1), however, showed SH expulsion ( $m/e$  117). The latter also arises by SH expulsion from the molecular ion ( $m/e$  151) followed by H expulsion. The major fragmentation of the  $m/e$  136 species appears to be loss of  $C_2H_2S$  to  $m/e$  78 followed by HCN expulsion to  $m/e$  51. Metastable defocusing also shows that SH loss is possible ( $m/e$  103).

In the low energy spectra (16 eV) the major peak is again at  $m/e$  136. The other important peaks were due to the molecular ion at  $m/e$  151 for XIIIa, and at  $m/e$  181 for XIIIb and VI, and to the  $[M-H]$  fragment at  $m/e$  150 for XIIIa and  $m/e$  180 for XIIIb. In addition the peaks at  $m/e$  111 ( $C_5H_5NS$ ),



at  $m/e$  79 ( $C_5H_5N$ ) and at  $m/e$  58 ( $C_2H_2S$ ) were slightly more intense than in the ordinary spectrum. Only very weak or no metastables were found for the formation of these ions. It is therefore believed that these species arise mainly by pyrolysis. The  $m/e$  111 ions correspond to pyrid-2-thione<sup>6</sup> and the  $m/e$  79 ions to pyridine.

Insertion of a methyl group into the pyridyl moiety (XIV and VII) does not change the nature of the spectra. The dominating pathway is the formation of a common intermediate at  $m/e$  150 corresponding to the  $m/e$  136 species above. The relative ion intensities varies somewhat. In Scheme 1 these ions are given in the parentheses.



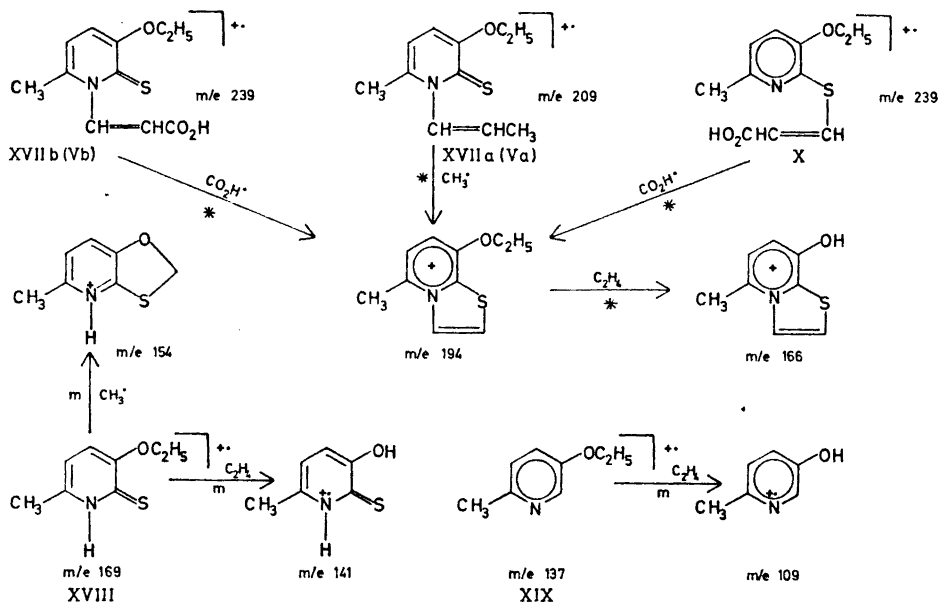
Scheme 2.

The spectra (Figs. 4–6) of the pyridyl hydroxy derivatives (XV and VIII) as well as their methyl homologues (XVI and IX) showed great similarities to the spectra for the desoxy series discussed above best illustrated by comparing Schemes 1 and 2. The initial fragmentation occurs in the vinyl side chain. Again the major fragmentation route goes through a common thiazolo[3,2-a]pyridinium cation ( $m/e$  152) formed by methyl or formyloxy radical loss from the respective molecular ions. The  $m/e$  152 species show little tendency to further fragmentation. Loss of  $C_2H_2S$  gives  $m/e$  94. CO expulsion to low intensity species at  $m/e$  124 was demonstrated by metastable defocusing. Betaine analogues of the postulated even electron cation ( $m/e$  152), however,

on ionization to the odd electron ion radical, have CO and CHO expulsions as their major fragmentation pathways.<sup>5</sup> The thiazolo ion radicals are also stabilized to a large extent and show only low tendency to fragmentation<sup>5</sup> as observed for the postulated thiazolo cation above.

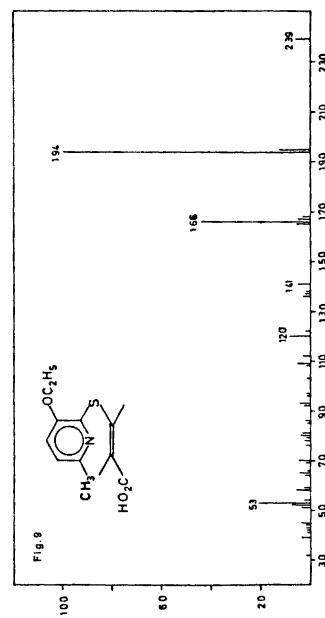
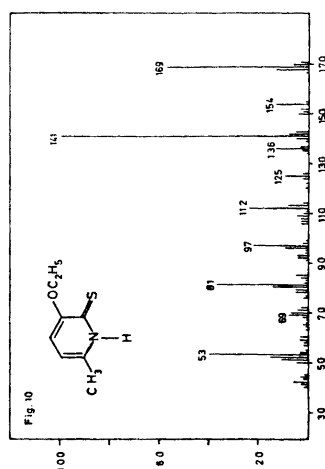
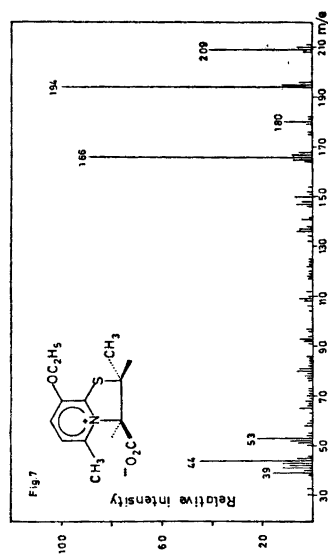
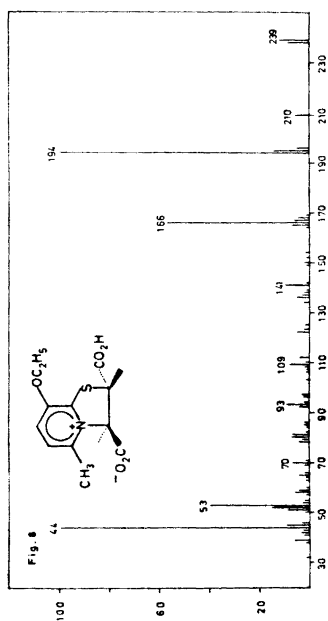
In addition to thiazolo-pyridinium formation, cleavage between the  $\alpha$ - and  $\beta$ -carbons in the side-chain can occur with the formation of an ion at  $m/e$  138. As the corresponding fragmentation in the desoxy pyridyl series was hardly observed the ion is formulated as a bicyclic structure over the pyridyl oxygen. This further fragments by CO ( $m/e$  110) or thioformyl radical ( $m/e$  93) expulsion. The intensity of the  $m/e$  138 fragment is highest for the *S*-vinyl derivatives (Fig. 6) and this seems reasonable since the other structures require a rearrangement prior to formation of these species.

3-Hydroxypyrid-2-thione and 3-hydroxypyridine give rise to the signals at  $m/e$  127 and  $m/e$  95.<sup>7</sup> These are considered to be mainly pyrolytic products for the same reasons as found in the desoxy series.



Scheme 3.

The spectra (Figs. 7–9) of the ethoxy analogues (XVII and X) are again very similar. Methyl or formyloxy radical expulsions from the respective molecular ions (Scheme 3) result in the formation of a common thiazolo[3,2-a]-pyridinium cation intermediate ( $m/e$  194). The otherwise important ethylene expulsion (see below) is unfavourable compared to formation of the bicyclic aromatic cation. Direct loss of the ethyl group is seen in the *N*-vinyl ( $m/e$  180,  $m/e$  210) but not in the *S*-vinyl analogue. Ethylene elimination from the  $m/e$



194 species gives rise to the only other important peak in the spectra ( $m/e$  166). As noted in the series above, M-H is present in both *N*-vinyl derivatives, especially in XVIIb, and is practically absent in the *S*-vinyl analogue (X).



Initial pyrolytic reactions are mainly responsible for the weak signals at  $m/e$  137 and  $m/e$  169. No metastable for their formation was seen. The former signal comes from 5-ethoxy-2-methylpyridine arisen through desulphurisation with loss of the side-chain. The electron induced fragmentation of this molecule is dominated by ethylene expulsion to the 5-hydroxy compound<sup>7</sup> and corresponds closely to the behaviour of 5-ethoxy-2-methylpyrimidine.<sup>8</sup>

Retention of the sulphur during the pyrolytic elimination of the side-chain gives 3-ethoxy-6-methylpyrid-2-thione (XVIII) ( $m/e$  169). Its spectrum (Fig. 10) has not previously been published and is therefore briefly discussed. Like its 5-ethoxypyrimidine analogue the base peak is due to ethylene expulsion to the corresponding 3-hydroxypyridine. The fragmentation of the latter<sup>7</sup> dominates the lower end of the spectrum.

Another characteristic fragment occurs at  $m/e$  154 and is due to methyl radical expulsion from the ethoxy group. This takes place through interaction with the neighbouring sulphur as postulated for the corresponding 5-ethoxypyrimid-4-thione.<sup>8</sup> Other minor, primary fragments are at  $m/e$  136 (M-SH) and at  $m/e$  125 (M-CH<sub>3</sub>CHO).

#### EXPERIMENTAL

The mass spectra were recorded on AEI MS-902 double focusing mass spectrometer. The source temperature was kept at 220–230°C. All compounds were introduced directly into the source. The electron energy was 70 eV and ionizing current 100  $\mu$ A. The low voltage spectra were run at 16 eV.

The preparation of compounds I–X will be described elsewhere.<sup>9</sup> Pyrolysis of Ia is described below.

*N*-(1-Propenyl)pyrid-2-thione (XIIIa). 2-Methyldihydrothiazolo[3,2-*a*]pyridinium-3-carboxylate (Ia) was pyrolyzed at 120°C/0.01 mmHg. A pale yellow oil was collected. (Found: C 63.72; H 6.22; N 9.30; S 20.85. Calc. for C<sub>8</sub>H<sub>8</sub>NS: C 63.55; H 6.00; N 9.26; S 21.21.)

#### REFERENCES

1. Hvistendahl, G. and Undheim, K. *Tetrahedron* **28** (1972) 1737.
2. Jennings, K. R. *J. Chem. Phys.* **43** (1965) 4176.
3. Undheim, K. and Hvistendahl, G. *Org. Mass. Spectrom.* **5** (1971) 325.
4. Undheim, K. and Hurum, T. *Acta Chem. Scand.* **26** (1972) 2385.
5. Reistad, K. R. and Undheim, K. *Acta Chem. Scand.* **25** (1971) 2954.
6. Lawrence, R. and Waight, E. S. *J. Chem. Soc. B* **1968** 1.
7. Undheim, K. and Hurum, T. *Acta Chem. Scand.* **26** (1972) 2075.
8. Undheim, K. and Hvistendahl, G. *Acta Chem. Scand.* **25** (1971) 3227.
9. Undheim, K. and Lie, R. *Unpublished*.

Received January 27, 1972.