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MASS SPECTROMETRY IN STRUCTURAL AND STEREOCHEMICAL PROBLEMS—XXXIX[1]

TROPANE ALKALOIDS[2]

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Abstract—The mass spectra of a series of tropane alkaloids have been measured and the major fragments identified, largely through the use of deuterium or substituent labelling. The principal bond fissions follow the paths laid down earlier for simple amines, cyclic ketones and alcohols, thus affording characteristic fragmentation patterns, which may prove useful in the characterization of unknown members of this class.

In the alkaloid field, mass spectrometry has been used largely in the structure elucidation of indole alkaloids,[4,5] but recently naturally occurring alkaloids of the quinoline,[6] isoquinoline,[6,7] aporphine[8] and colchicine[9] classes have also been examined with success. All of these bases were characterized by the presence of an aromatic nucleus and we should now like to discuss the mass spectrometric fragmentation behaviour of an alicyclic class—the tropane group.[10] This group, containing amine, carbonyl and hydroxyl functions, was chosen in order to test the validity and possible generalizations of the fragmentation modes established earlier for amines,[11] cyclic ketones[12] and cyclic alcohols[13] in a saturated bicyclic system.

[1] Paper XXXVIII, H. Budzikiewicz, C. Djerassi, F. Puisieux, F. Percheron and J. Poisson, *Bull. Soc. Chim. Fr.* 1899 (1963).

[2] The work at Stanford University was supported by the National Institutes of Health (grant No. AM-04257) of the U.S. Public Health Service.

[3] National Institutes of Health postdoctorate fellow, 1962–1963.

[4] See K. Biemann, *Mass Spectrometry*, Chap. 8, McGraw-Hill, New York (1962).

[5] For references not covered in ref. 4 see C. Djerassi, *Pure Appl. Chem.* **6**, 575 (1963); G. Spiteller and M. Spiteller-Friedmann, *Tetrahedron Letters* 147 (1963); C. Djerassi, H. Budzikiewicz, R. J. Owellen, J. M. Wilson, W. G. Kump, D. J. LeCount, A. R. Battersby and H. Schmid, *Helv. Chim. Acta* **46**, 742 (1963).

[6] G. Spiteller and M. Spiteller-Friedmann, *Tetrahedron Letters* 153 (1963).

[7] H. Budzikiewicz, S. L. Pakrashi and H. Vorbrüggen, *Tetrahedron* **20**, 399 (1964).

[8] M. Ohashi, J. M. Wilson, H. Budzikiewicz, M.Shamma, W. A. Slusarchyk and C. Djerassi, *J. Amer. Chem. Soc.* **85**, 2807 (1963).

[9] J. M. Wilson, M. Ohashi, H. Budzikiewicz, F. Santavy and C. Djerassi, *Tetrahedron*, **19**, 2225 (1963).

[10] For pertinent references see G. Fodor, *Acta Chim. Acad. Sci. Hung.* **5**, 379 (1955); G. Fodor, *Tetrahedron* **1**, 86 (1957); G. Fodor, *Chem. Ind.* 1500 (1961); G. Fodor, S. Kiss and A. Heusner, *Chem. Ind.* 372 (1963); G. Fodor, *The Tropane Alkaloids*, in *The Alkaloids* (Edited by R. A. F. Manske) Vol. 6. Academic Press, New York (1960).

[11] Z. Pelah, M. A. Kielczewski, J. M. Wilson, M. Ohashi, H. Budzikiewicz and C. Djerassi, *J. Amer. Chem. Soc.* **85**, 2470 (1963) and references cited therein.

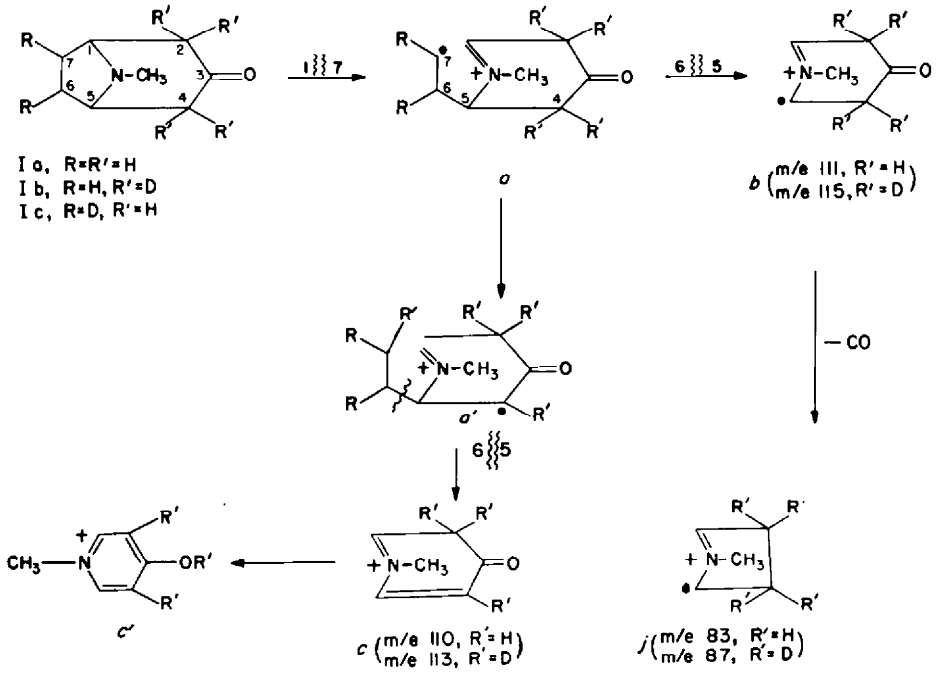
[12] E. Lund, H. Budzikiewicz, J. M. Wilson and C. Djerassi, *J. Amer. Chem. Soc.* **85**, 941, 1528 (1963) and references cited therein.

[13] P. Natalis, *Bull. Soc. Royale Sci. Liege* **31**, 790 (1962). H. Budzikiewicz, Z. Pelah and C. Djerassi, *Monatsh.* in press.

The simplest representative is tropinone (Ia), which contains two functional groups (methylamino and carbonyl), the presence of which can be expected to favour rupture of certain bonds upon electron bombardment. It has already been demonstrated earlier[4,11,14] that cleavage of carbon-carbon bond next to a nitrogen atom is a very favored process, since it leads to stabilization of the positive charge by formation of an ammonium ion with participation of the unshared pair of electrons of the heteroatom. The formation of all of the major fragments in the spectrum (Fig. 1a) of tropinone (Ia) can be rationalized by the operation of such step, once the molecular ion is produced. In that connection it is pertinent to point out that molecular ion peaks (e.g. *m/e* 139 in Fig. 1a) could be detected readily in all of the tropane alkaloid spectra examined by us, thus indicating the utility of this method for the determination of empirical formulae among this group of bases.

Rupture of the 1–7 bond (equivalent to the 5–6 bond in this symmetrical molecule) in tropinone (Ia) would lead to an intermediate *a*, which may decompose further by simple homolytic cleavage of the 5–6 linkage, yielding the radical ion *b* (*m/e* 111 in Fig. 1a). Odd-electron species are generally less stable[14] than even-electron ions and apparently is the driving force for the formation of the *m/e* 110 fragment ($c = c'$). We visualize this process as initial capture of one of the C-4 hydrogens by the primary free radical site at C-7 in *a* to produce the secondary free radical *a'*, which would then undergo fission of the 5,6-bond to yield the ion *c* (*m/e* 110), which probably exists as the completely aromatic tautomer *c'*.

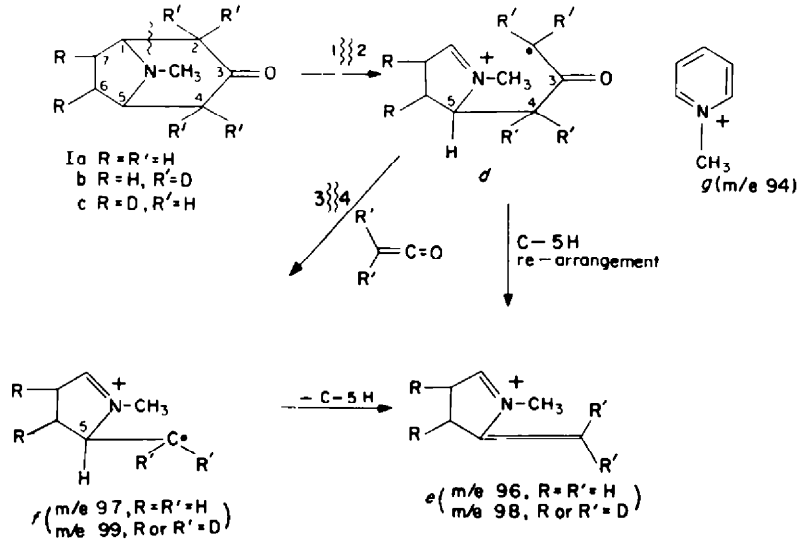
The correctness of these proposals could be established by labelling positions 2 and 4 (Ib) or 6 and 7 (Ic) with deuterium. As expected, in the spectrum of the 6,7-d_2



[14] *Mass Spectrometry of Organic Ions* (Edited by F. W. McLafferty) Chap. 7. Academic Press, New York (1963).

analog Ic, both fragments (*b* and *c*) possess the same mass (*m/e* 111 and 110) as the unlabelled precursor Ia, since carbon atoms 6 and 7 are lost. In the 2,2,4,4-d_4 ketone Ib, however, ion *b* occurs (see Fig. 1b) at *m/e* 115 (retention of all four deuterium atoms), while *c* is shifted to *m/e* 113 (retention of three deuterium atoms), since one deuterium is involved in the rearrangement step ($a \rightarrow a'$).

If instead of the 1–7, the alternate 1–2 (or 4–5) bond is broken, intermediate *d* is produced, which can undergo several well precedented fragmentations. The most obvious one would be fission of the 3–4 bond—the favored cleavage process of aliphatic ketones[15]—to yield ketene and species *f* (*m/e* 97), which may undergo the further loss of the C-5 hydrogen atom to give species *e* (*m/e* 96 in Fig. 1a). The presence of a partially obscured metastable ion at *m/e* 95·2 (calc. 95·1) seems to corroborate such a hydrogen loss. Whether the ion *e* is formed partly also directly from the molecular ion (see $d \rightarrow e$) is a moot point. The two deuterium labelled analogs Ib and Ic support the suggested mechanisms: the mass spectra of both Ib (see Fig. 1b) and Ic exhibit peaks at *m/e* 98 and 99 (shift of two mass units corresponding to the retention in either example of two deuterium atoms in the ionized portion) in accordance with structures *e* and *f*.

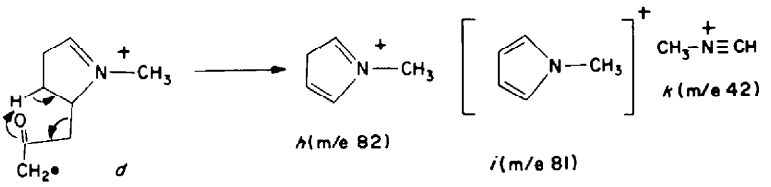


An ion of low abundance, but present in the spectra of all tropane alkaloids, occurs at *m/e* 94 and may be attributed to the N-methylpyridinium cation *g*. Support for this assignment comes from the observed shift (see Fig. 1b) to *m/e* 95 and 96 in the spectrum of the 2,2,4,4-d_4 species Ib, while in the 6,7-d_2 analog Ic, the major part remains at *m/e* 94.

Ions *e* and *f* are proposed to arise from the well-known[15] α-fission of the ketone *d*. Rupture of the β-bond of ketones[12] may also lead to stable fragments and such a process is also noted in the spectrum (Fig. 1a) of tropinone (Ia). Thus cleavage of the 4–5 linkage in *d*, β to the carbonyl group, with migration of the γ-hydrogen (C-6) through the generally accepted[16] six-membered intermediate (arrows in *d*), will

[15] A. G. Sharkey, J. L. Schultz and R. A. Friedel, *Analyt. Chem.* **28**, 934 (1956).

yield the ion *h* (*m/e* 82), which represents the base peak in the mass spectrum (Fig. 1a) of tropinone (Ia). This ion is accompanied by a less abundant one of *m/e* 81, whose genesis requires a double hydrogen transfer and for which structure *i* is proposed.



In the spectrum (Fig. 1b) of the 2,2,4,4-d_4 analog Ib, fragments *h* and *i* still occur at *m/e* 82 and 81, since all four labels are lost in the process. The spectrum of 6,7-d_2-tropinone (Ic) shows extensive scrambling in this peak group, since either hydrogen or deuterium can be lost during the formation of *h* and *i*. The tropinone spectrum (Fig. 1a) exhibits a smaller peak at *m/e* 83, part of which must be due to further decomposition of species *b* by loss of carbon monoxide, since a partial movement of this peak to *m/e* 87 is noted in the spectrum (Fig. 1b) of the 2,2,4,4-d_4 species Ib. This type of carbon monoxide expulsion is of greater importance in the 6- and 7-oxygenated tropinones (II, III) and a plausible representation for the *m/e* 83 ion is *j*.

Another typical fragment of this class of alkaloids, which can be observed in all of the tropane spectra, occurs at *m/e* 42 and is best represented by *k*. As expected, it is not affected by deuterium labelling at positions 2,4,6 and 7 (Ib or Ic).

At this point, it is worth noting that an earlier enunciated generalization[14,17]—the tendency of even-electron ions to be more abundant than odd-electron ones—is nicely supported by the spectrum (Fig. 1a) of tropinone (e.g. *c vs. b*; *e vs. f*; *h vs. i*)

In the indole alkaloid series,[4,5] the presence of additional methoxyl groups in the aromatic portion[18] of the molecule did not influence to any extent the fragmentation behavior of the parent (demethoxy) compound, because of preferred bond fission in the alicyclic portion of the molecule and this property has been employed to great advantage[4] for labelling purposes. In simpler and largely aromatic alkaloids,[8] the presence of methoxyl groups plays a much more important role and the same statement applies to oxygenated substituents at C-6 and C-7 of the tropane skeleton.

The most abundant ion in the spectrum (Fig. 2) of 6β-methoxytropinone (II) and of teloidinone (IIIa, Fig. 3) as well as the latter's acetonide (IIIb) occurs at *m/e* 111 (b). This behavior is understandable, since primary cleavage will be favored between the two functionalized carbon atoms (C-5 and C-6 in II). Abstraction of a C-2 hydrogen atom will not be as favored as in I, since either free radical will be secondary, in contrast to the analogous process in I ($a \rightarrow a'$), where a primary radical is transformed into a secondary one. It is not surprising, therefore, that ion *b* (*m/e* 111) is now much more intense (see Figs. 2 and 3) than *c* (*m/e* 110).

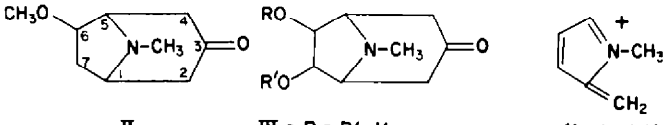
Fragment *b* decomposes further through explusion of carbon monoxide to species

[16] F. W. McLafferty, *Analyt. Chem.* **31**, 82 (1959).

[17] See also H. Budzikiewicz, C. Djerassi, G. W. Kenner, A. H. Jackson, D. J. Newman and J. M. Wilson, *J. Chem. Soc.* in press.

[18] This applies even to a large extent to the aliphatically bound methoxyl group in pyrifoline and refractidine; B. Gilbert, J. M. Ferreira, R. J. Owellen, C. E. Swanholm, H. Budzikiewicz, L. J. Durham and C. Djerassi, *Tetrahedron Letters* 59 (1962).

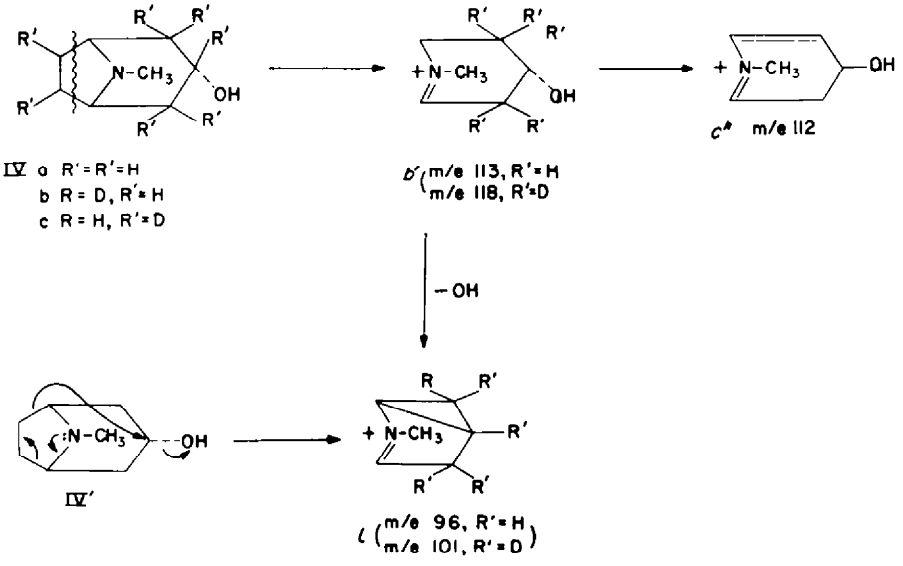
j (*m/e* 83). The operation of this process is supported by the existence of a metastable ion at *m/e* 62·5 (calc. 62·1 for the transition *m/e* 111 → 83). It will be noted that the peak at *m/e* 94 is much more intense in the spectrum (Fig. 2) of 6β-methoxytropinone (II) than in that (Fig. 1a) of tropinone (Ia) itself. While part of it can certainly be attributed to species *g*, the other contributor may well be *e*-MeOH (=*e'*), which is covered below in the discussion of the mass spectra of acetyl tropine derivatives (VIII) and 6,7-dehydro compounds (IX).



II III a R = R' = H b R = R' = $X^{CH_3}_{CH_3}$ *e'* (m/e 94)

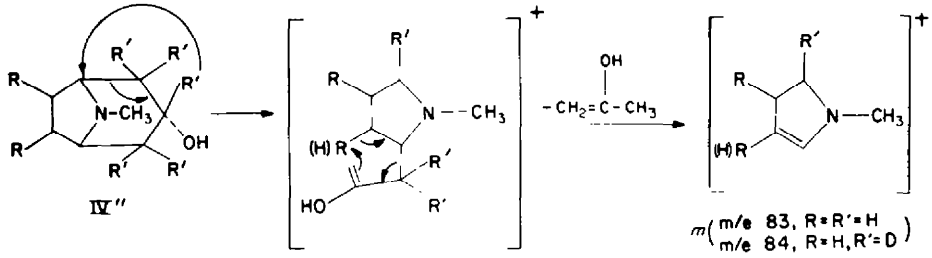
We shall now turn to a consideration of those tropanes, where the keto group at C-3 is replaced by a hydroxyl function. The mass spectrum (Fig. 4) of the simplest analog, tropine (IVa) exhibits a pronounced loss of 17 mass units (M—OH) at *m/e* 124, but otherwise its fragmentation pattern resembles that (Fig. 1a) of the corresponding ketone Ia. Thus, the loss of carbon atoms 6 and 7 with or without hydrogen transfer (*b'* and *c'*) occurs, while the peak at *m/e* 96 is made up of two species.

About two thirds of it corresponds to ion *e* and shows the anticipated shift to *m/e* 98 in the 6,7-d_2 (IVb) or 2,2,3,4,4-d_5 (IVc) analogs. Approximately one-third of it remains at *m/e* 96 in 6,7-d_2-tropine (IVb), but is shifted to *m/e* 101 in the d_5-derivative IVc. Clearly, C-6 and C-7 are eliminated (wavy line in IV) with generation of *b'*, which may now lose the hydroxyl group to yield the even-electron ion *l* or a concerted process may operate (arrows in IV') to afford *l* directly.

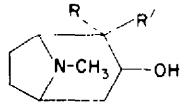


Ion *f* can be noted in Fig. 4 at *m/e* 97, *g* at *m/e* 94 and *k* at *m/e* 42. Fragment *h* (*m/e* 82) is again the base peak, just as was found (Fig. 1a) in tropinone (Ia), and it

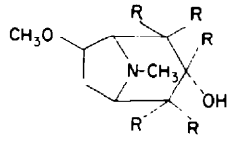
undergoes the expected behavior upon deuteration, namely scrambling between *m/e* 82, 83, and 84 in 6,7-d_2-tropine (IV*b*) and no shift in the d_5-analog IVc. The *m/e* 82 ion *h* is accompanied by a rather abundant satellite at *m/e* 83 (*m*), whose origin must be different from that of species *j* observed earlier in the spectra (Figs. 1–3) of the ketones I–III. The justification for this statement is the shift to *m/e* 84, incident to deuteration at positions 2, 3 and 4 (IVc), and (at least in part[19]) to *m/e* 85 in 6,7-d_2-tropine (IVb). A double hydrogen rearrangement as illustrated in IV″ would serve to rationalize these observations.



The mass spectra of ecgonine (Va) and ψ-ecgonine (Vb, Fig. 5) exhibit all of the characteristic features noted with tropine (IV, Fig. 4): M—OH (*m/e* 168), *m/e* 157 and 156 (analogs of *b* and *c*), *e* and *f* (*m/e* 96 and 97), *g* (*m/e* 94, *h* and *m* (*m/e* 82 and 83) and *k* (*m/e* 42). In addition, several fragments caused by the presence of the carboxyl function can be observed in Fig. 5: *m/e* 141 (M-44 (CO_2)), *m/e* 140 (M-45 (CO_2H)) and *m/e* 112 (loss of CO_2 from *m/e* 156 or loss of CO_2H from 157). The spectra of the two isomers Va and Vb are very similar with the exception that ecgonine (Va) exhibits a substantial peak at *m/e* 124, which might be due to the expulsion of carbon dioxide from the M-17 fragment (*m/e* 168 in Fig. 5).



V a R=H, R'= CO_2H
b R= CO_2H, R'=H



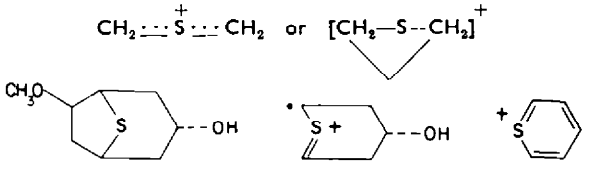
VI a R=H
b R=D

Just as in the tropinone series (II), introduction of a methoxyl substituent at C-6 of tropine alters greatly the abundance of certain fragments. In the mass spectrum (Fig. 6) of 6β-methoxytropine (VIa) the most important ion is *b'* (*m/e* 113), which loses its hydroxyl group to yield species *l* (*m/e* 96). The shifts observed in the 2,2,3,4,4-d_5-analog VIb (*b'* *m/e* 118, *l* *m/e* 101) are in agreement with this formulation. The peaks (Fig. 6) at *m/e* 94 (*e'*, *g*), 82 (*h*) and 42 (*k*) have already been discussed earlier, while the relatively small one at *m/e* 122 may be due to the loss of hydroxyl and methanol from the molecular ion, since it appears at *m/e* 126 in the spectrum of the 2,2,3,4,4-d_5 derivative VIb.

The thia analog VII of methoxytropine (VI) exhibits (Fig. 7) an analogous fragmentation behavior, one of the most important peaks occurring at *m/e* 116 (*n*, the

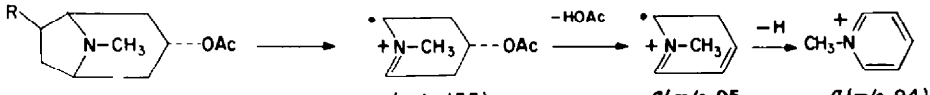
[19] In view of the shifts in fragment *j* (*m/e* 83), those in *m* cannot be followed unambiguously. However a comparison of the ratio *m/e* 82 : *m/e* 83 (10 : 6·7) in IVa with that (10 : 4·4) of Σ *m/e* 82 + 83 + 84: *m/e* 85 shows that peak *m* shifts only partially to *m/e* 85 in IVb.

thia analog of *b'*). Other noteworthy cleavage products are seen at *m/e* 156 (M—H_2O rather than M—OH as noted in tropine and its derivatives), *m/e* 142 (M—S), *m/e* 141 (M—SH), *m/e* 97 (the thiapyrylium cation *o*) and especially at *m/e* 60, which is most likely the sulfur analog of *k* or related species such as



VII *n* (m/e 116) *o* (m/e 97)

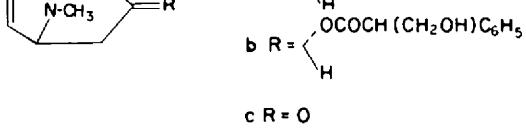
The mass spectral fragmentation behaviour of the acetyl derivatives VIII of tropine is governed by the ready initial loss of the elements of CH_3CO_2 or CH_3CO_2H. In the C-6 substituted tropine acetates VIIIa (Fig. 8), VIIIb and VIIIc, the most abundant ion is *m/e* 94. The presence of a sharp metastable ion at *m/e* 93·2 (calc. 93·2 for the transition *m/e* 95 → 94) suggests that it is formed, at least in part, by the loss of a hydrogen atom from the *m/e* 95 species, which in turn can be represented by *q*. To what extent *m/e* is due to *e'* and to *g* cannot be answered readily, but the presence of a very pronounced *m/e* 94 peak in the spectra of the 6,7-dehydro derivatives IX suggest that *e'* plays an important role.



VIII a R=OCH_3 b R=OH c R=OAc *p* (m/e 155) *q* (m/e 95 *g* (m/e 94)

The further fragmentations proceed along expected lines and include (i) the elimination of the elements of CH_3CO (M-43) and CH_3CO_2 (M-59), which can undergo further loss of ROH (R = CH_3, H or Ac) to give an ion of mass *m/e* 122; (*ii*) formation of the acetyl analog *p* (*m/e* 155) of *b'*, followed by loss of an acetoxyl radical (*l* = *m/e* 96) or of acetic acid (*q* = *m/e* 95), the latter representing a precursor of the ion *g* (*m/e* 94); (iii) the production of the ions *k* (*m/e* 42) and *m/e* 43 (CH_3CO^+).

Finally, there has been examined the effect of an additional double bond in the fived-membered ring. By far the most important peak in the spectra of 6,7-dehydrotropine (IXa, Fig. 9a), its tropic acid ester IXb (Fig. 9b) or 6,7-dehydrotropinone (IXc) occurs at *m/e* 94 and most likely consists of species *g* and *e'*. As is to be expected, 6,7-dehydrotropine (IXa) exhibits (Fig. 9a) the loss of hydroxyl (M—OH ion at *m/e* 122), while the spectrum (Fig. 9b) of the tropic acid ester contains peaks ascribable to ions arising from loss of R (*m/e* 138), RO (*m/e* 122) and ROH (*m/e* 121), R being the tropyl fragment $C_6H_5CH(CH_2OH)CO$.



IX

In summary, it can be stated that the formation of the major fragment ions of the tropane ring system after electron impact can be rationalized by assuming primary cleavage of one of the carbon-carbon bonds adjacent to nitrogen, further bond fission (with and without hydrogen rearrangement) then being governed by the presence of other substituents. Since these additional functional groups influence the relative abundance of the different fragments, a given substance can in general be assigned with ease to a given subclass of the tropane alkaloids. Since the more complicated

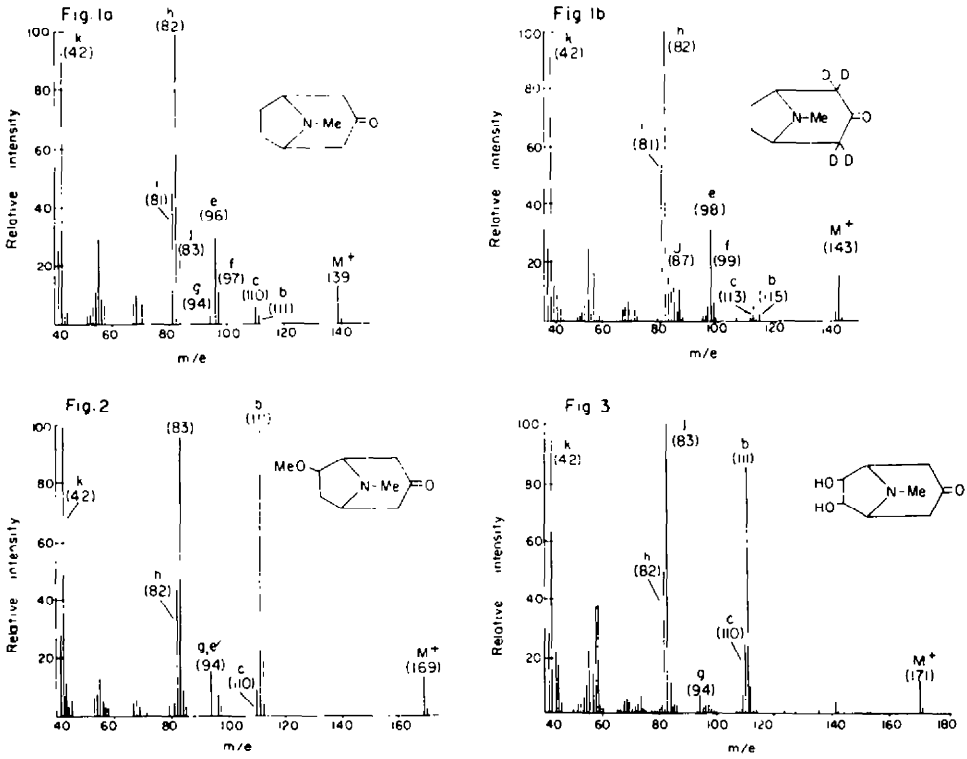


FIG. 1a Mass spectrum of tropinone (Ia).

FIG. 1b Mass spectrum of 2,2,4,4-d_4-tropinone (Ib).

FIG. 2 Mass spectrum of 6β-methoxytropinone (II).

FIG. 3 Mass spectrum of teloidinone (IIIa).

esters (e.g. tropic acid esters) yield a fairly complex pattern, due to competing fragments of the acid portion, mass spectral investigations of unknown members of this class will yield much more useful information if performed on the saponified alcohol or the derived ketone.

EXPERIMENTAL

All mass spectra were measured with a CEC mass spectrometer model 21-103C equipped with a heated (200°) all-glass inlet system, the ionizing energy having been set at 70 eV and the ionizing current at 50 μA.

2,2,4,4-d_4-*Tropinone* (Ib). A 10 mg sample of tropinone in a solution prepared from 2 ml deuteriomethanol, 10 mg Na and 0·5 ml deuterium oxide was heated under reflux for 1 hr. The solution was cooled and evaporated under red. press. The residue was taken up in ether and washed with a small portion of deuterium oxide. The ethereal solution was dried ($MgSO_4$) and evaporated to yield 10 mg crystalline ketone, m.p. 38°.

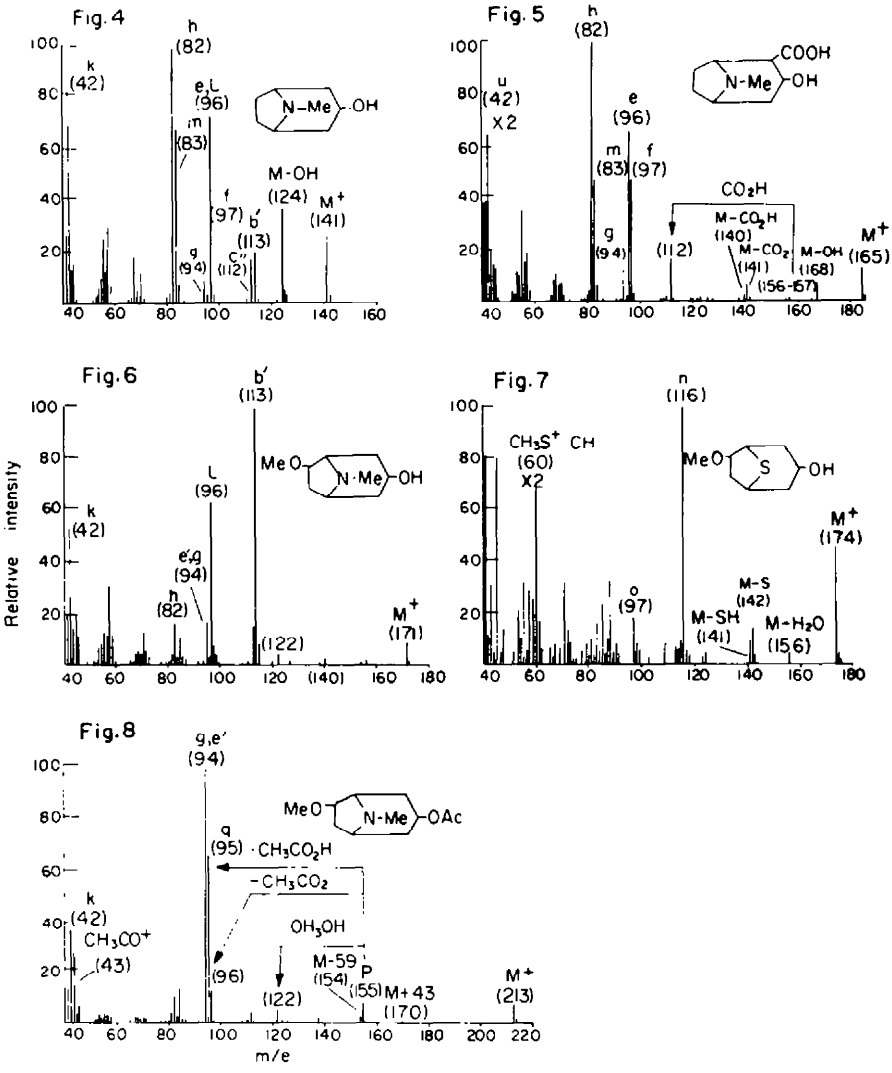


FIG. 4 Mass spectrum of tropine (IVa).

FIG. 5 Mass spectrum of ψ-ecgonine (Vb).

FIG. 6 Mass spectrum of 6β-methoxytropine (VIa).

FIG. 7 Mass spectrum of thia analog VII of 6β-methoxytropine

FIG. 8 Mass spectrum of 6β-methoxytropine acetate (VIIIa).

2,2,4,4-d_4-6β-*Methoxytropinone.* A similar exchange as that described above was carried out on 100 mg 6β-methoxytropinone in a solution of 8 ml deuteriomethanol, 0·5 ml deuterium oxide, and 20 mg Na which was heated under reflux for 15 min. Work-up of the reaction mixture gave 95 mg of a clear oil, the homogeneity of which was demonstrated by thin-layer chromatography.

2,2,3,4,4-d_5-*Tropine* (IVc). A solution of 5 mg 2,2,4,4-d_4-tropinone in 2 ml anhydrous ether was treated with 2 mg lithium aluminum deuteride at room temp for 1 hr with stirring. The excess deuteride was decomposed with wet ether and $MgSO_4$ added. The mixture was filtered and the filtrate evaporated to yield 3 mg d_5-tropine.

Table 1. Isotopic purity of labelled compounds

Compound	Isotope composition (%)						Relative peak heights							
	d_0	d_1	d_2	d_3	d_4	d_5	M − 1	M	M + 1	M + 2	M + 3	M + 4	M + 5	M + 6
6,7-d_2-Tropinone	8	19	73				0·01	0·09	0·33	1·00	0·13	0·01		
2,2,4,4-d_4-Tropinone			2	14	84					0·02	0·16	1·00	0·11	0·02
Tropinone							0.20	1·00	0·56	0·06				
6,7-d_2-Tropine	1	23	76				0·01	0·07	0·32	1·00	0·41	0·05		
2,2,3,4,4-d_5-Tropine				13	20	67					0·40	0·50	1·00	0·30
Tropine							0·20	1·00	0·40	0·03				
2,2,3,4,4-d_5-6β-Methoxytropine			5	14	33	48				0·10	0·30	0·70	1·00	0·15
6β-Methoxytropine								1·00	0·15	0·02				
2,2,4,4-d_4-6β-Methoxy-tropinone			10	29	61					0·17	0·48	1·00	0·64	0·25
6β-Methoxytropinone							0·20	1·00	0·56	0·06				

2,2,3,4,4-d_5-6β-*Methoxytropine*. A solution of 40 mg 2,2,4,4-d_4-6β-methoxytropinone in 5 ml anhydrous ether was treated with 10 mg lithium aluminium deuteride at room temp for 1 hr with stirring. Work-up as described above yielded 30 mg of clear oil, shown by thin-layer chromatography and IR spectrum to be the alcohol.

6,7-d_2-*Tropine* (IVb). A solution of 200 mg 6-dehydrotropine in 40 ml cyclohexane was reduced with deuterium and 10% Pd–C catalyst for 1 hr at room temp and atm. press. The catalyst was then removed by filtration and washed well with ether. The combined filtrates were evaporated *in vacuo* to yield 194 mg (94%) of crystalline d_2-tropine, m.p. 58°.

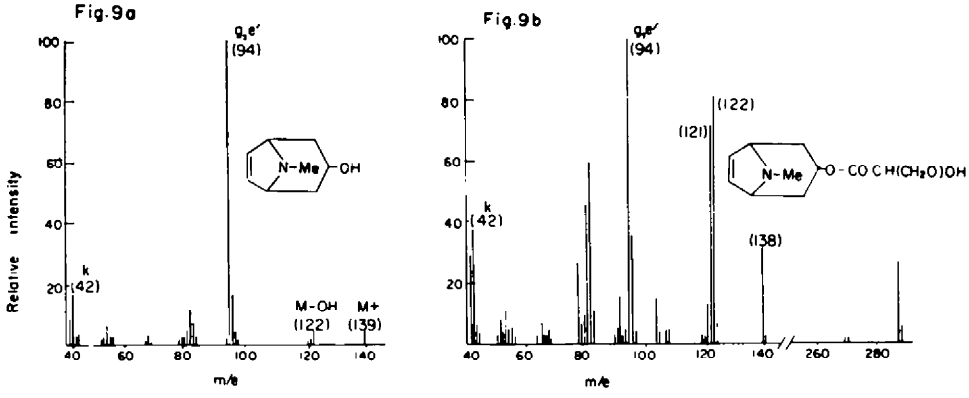


FIG. 9a Mass spectrum of 6,7-dehydrotropine (IXa).

FIG. 9b Mass spectrum of 6,7-dehydrotropine tropic acid ester (IXb).

6,7-d_2-*Tropinone* (Ic). To a stirred solution of 45 mg of the above d_2-tropine in 10 ml distilled acetone was added at 0° under N_2 0·2 ml 8 N chromium trioxide (Jones reagent). The mixture was stirred for an additional 5 min and poured into water. The mixture was neutralized with 1 N NaOH and extracted twice with ether. The ethereal solution was washed 3 times with water, dried ($MgSO_4$), and evaporated to yield 27 mg of a clear oil. The oil was subjected to preparative thin-layer chromatography on silica gel (developed with acetone–methanol 1:1) to yield 17 mg of crystalline ketone, m.p. 42°.

6-*Dehydrotropinone* (IXc). The above procedure was used to oxidize 100 mg 6-dehydrotropine (IXa) using 0·3 ml 8 N Jones reagent. Isolation of the ketone by preparative thin-layer chromatography (silica gel, acetone–methanol 1:1) gave 93 mg of a clear oil.