MASS SPECTRA OF SOME SESQUITERPENE LACTONES OF THE EUDESMANE SERIES WITH A C_1 – OH GROUP

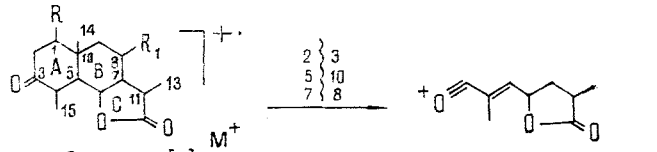
U. A. Abdullaev, Ya. V. Rashkes, V. A. Tarasov, and Sh. Z. Kasymov

UDC 543.51 + 547.314

An analysis of literature information on the fragmentation of individual representatives of sesquiterpene lactones of the germacrane and eudesmane series [1-5] does not show any definite regularity in the mass-spectrometric behavior of these compounds. It is obvious that the nature and position of oxygen substituents sharply changes the pattern of breakdown.

We have suggested that a partial solution to this problem consists in the consideration of a set of lactones with one constant substituent and one or two variable ones, and for this purpose we have taken a number of eudesmanolides with a C_1–OH group: arsanin (I) [6], arabsin (II) [7], and artecalin (III) [8] and their acetates (IV, V, VI), and dihydroarabsin (VII) and dihydroarsubin (VIII) [9].

The mass spectra of arsanin (I) and its stereoisomer at C_1–OH, arsantin, and of their acetates were given in a paper in which the structures of these compounds were proved by independent synthesis [10], but the authors concerned did not discuss fragmentation processes. It has been reported [1-3, 5] that in the first stage of the fragmentation of the M^+ ions the ions $(M-CH_3)^+$, $(M-H_2O)^+$, and $(M-CO)^+$ are formed and the elements of the lactone ring are split out, giving peaks of variable intensity. In the fragmentation of arsanin (I), the ejection of the lateral fragments takes place to an insignificant degree and the fragmentation process leads mainly to the formation of an ion with m/e 167 (Fig. 1). The same pattern of fragmentation is given by arabsin (II), for which the structure of 8-hydroxy-3-oxoeudesmanolide (IIa) was previously put forward. In addition to this, the spectra of the acetates of (IV) and (V) are similar. If we neglect the low probability of the production of similar spectra in the fragmentation of structures (I) and (IIa), the formation of the fragment with m/e 167 can be illustrated in the following way:



I. R=OH; R_1=H [6] 266
IIa. R=H; R_1=OH [7] 266
IX. R = R_1=H 250

167 $C_9H_{11}O_3$ (I, IIa, IX)

Scheme 1

However, in the spectrum of β-tetrahydrosantonin (IX), the molecule of which lacks an OH group in the 3-decalone ring, no similar direction of fragmentation is observed. The spectrum of (IX) is characterized by a multitude of peaks and the splitting of the majority of the strong peaks in the high-resolution spectrum into doublets of triplets, which shows different routes for the fragmentation of the M^+ ion of (IX). The peak of an ion with m/e 167 is a triplet the components of which have the compositions $C_9H_{11}O_3$ (0.06)*, $C_{10}H_{15}O_2$ (0.64), and $C_{11}H_{19}O$ (0.3). The ion with the composition $C_9H_{11}O_3$ is probably formed by Scheme 1, but in very small amount.

The ion with a mass number of 167 in the spectrum of arsanin (I) is a singlet and has the composition $C_{10}H_{15}O_2$, which agrees with the strongest component of the ion of the same mass from tetrahydrosantonin (IX). This circumstance is evidence in favor of the assumption that the fragment with m/e 167 (I) and (IX) originates by the cleavage of the C_1-C_{10} and C_4-C_5 bonds with the migration of one hydrogen from the neutral fragment.

* The relative amount of the ion of the given composition in the measured peak.

Institute of the Chemistry of Plant Substances, Academy of Sciences of the Uzbek SSR, Tashkent. Translated from Khimiya Prirodnykh Soedinenii, No. 1, pp. 34-40, January-February, 1979. Original article submitted October 27, 1978.

0009-3130/79/1501-0028 $07.50

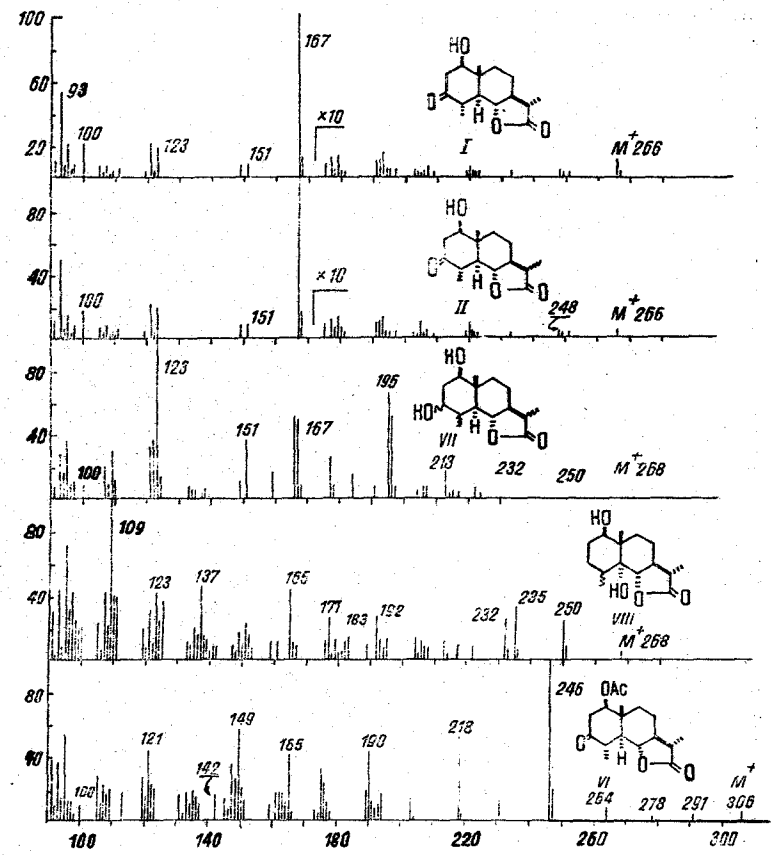


Fig. 1. Mass spectra of arsanin (I), arabsin (II), dihydroarabsin (VII), dihydroarsubin (VIII), and artecalin acetate (VI).

In addition to the practical identity of the spectra of (I) and (II), and also of those of the acetates (IV) and (V), the shifts of the mass numbers of the fragments in the spectra of the OD analogs (I) and (II) and in the spectra of the products of the replacement of H at C_2 and C_4 by D in a weakly alkaline deuterodiethylamine medium also coincide. This indicates the absence of a substituent at C_8 in the arabsin (II) molecule. It is most likely that arsanin (I) and arabsin (II) are stereoisomers.

The maximum intensity of the peak with m/e 167 in their spectra is due to the preferential cleavage of the bond at the quaternary C_{10} atom activated by the presence of an OH group at C_1. Here it is possible to draw an analogy with the fragmentation of 1-oxo-5α-androstane [11]. To test this hypothesis, let us consider the mass spectra of artecalin (III), dihydroarabsin (VII), and dihydroarsubin (VIII). In these spectra the above-mentioned fragmentation pathway is retained in all cases (scheme 2) and only the mass numbers vary. In the case of artecalin (III), the maximum ion contains 165 m.u. and in the case of dihydroarbusin (VIII) 183 (167 + 16) m.u. Then the ions with m/e 167, 165, and 183 break up with the ejection of a molecule of water and of the elements of the lactone ring. The spectra of (VII) and (VIII) contain satellite ions with m/e 166 and 182, respectively, formed without the migration of a hydrogen atom. **(See scheme 2 on following page.)**

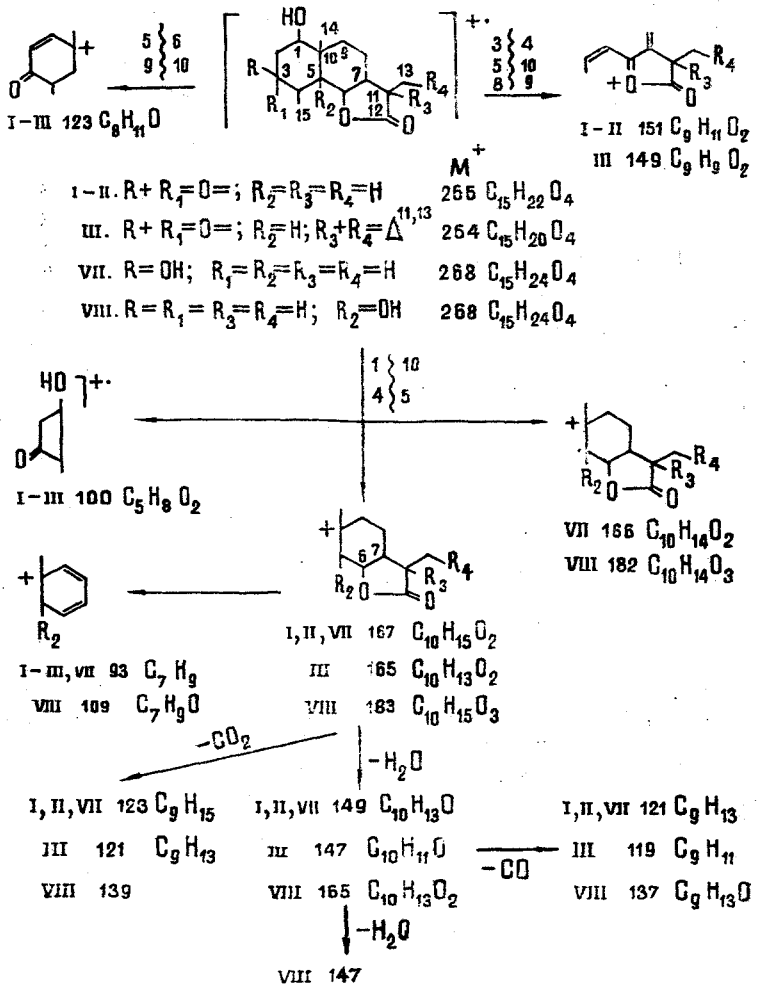
In similar bond cleavages in the cases of compounds (I), (II), and (III) an ion with m/e 100 and the composition $C_5H_8O_2$ arises from the elements of ring A (see Fig. 1 and Table 1), which is confirmed by the shift of the peak of this ion in the spectrum of the OD analogs by 1 and 4 amu in the spectra of the products of alkaline deuteration. However, in the spectra of dihydroarabsin (VII) ions with such a composition can be formed not only with the inclusion of the elements of ring A after the elimination of two atoms of hydrogen but also from the lactone ring C with the migration of two hydrogen atoms to the charged fragment. Only the second variant is possible for dihydroarsubin (VIII).

The spectrum of arsubin acetate (VI) completely reproduces the pattern of the acetates (IV) and (V), but with a shift of the peaks of all the key ions by 2 amu in the direction of low masses. A feature of the spectra of the acetates (IV–VI) is the elimination from M^+ of a CH_3COOH molecule, which, in these cases, leads to the peak of maximum intensity. Apart from this, the fragmentation of the acetyl group at C_1 takes place by the ejection

TABLE 1. Results of Measurements of the Accurate Masses of the Ions of Compounds (I), (III), and (VI)-(VIII)

Arsanin (I)			Artecalin (III)			Artecalin acetate (VI)			Dihydroarabsin (VII)			Dihydroarsubin (VIII)					
266	$M^+C_{15}H_{22}O_4$	1*	264	$M^+C_{15}H_{20}O_4$	1	306	$M^+C_{17}H_{22}O_5$	1	268	$M^+C_{15}H_{24}O_4$	1	268	$M^+C_{15}H_{24}O_4$	1	165	$C_{10}H_{13}O_2$	1
167	$C_{10}H_{15}O_2$	1	165	$C_{10}H_{13}O_2$	1	246	$C_{15}H_{18}O_3$	1	196	$C_{12}H_{20}O_2$	1	222	$C_{14}H_{22}O_2$	1	151′	$C_9H_{11}O_2$	0,5
151′	$C_9H_{11}O_2$	0,9	149′	$C_9H_9O_2$	0,6	165	$C_{10}H_{13}O_2$	1	195	$C_{12}H_{19}O_2$	1	213	$C_{11}H_{17}O_4$	1	151″	$C_{10}H_{15}O$	0,5
151″	$C_{10}H_{15}O$	0,1	149″	$C_{10}H_{13}O$	0,25	142	$C_7H_{10}O_3$	1	177	$C_{12}H_{17}O$	1	204	$C_{14}H_{20}O$	1	149′	$C_{10}H_{13}O$	0,5
149′	$C_9H_9O_2$	0,05	149‴	$C_{11}H_{17}$	0,15	100	$C_5H_8O_2$	1	167	$C_{10}H_{15}O_2$	1	195′	$C_{12}H_{19}O_2$	0.35	149″	$C_{11}H_{17}$	0,5
149″	$C_{10}H_{13}O$	0,9	147	$C_{10}H_{11}O$	1	93	C_7H_9	1	166	$C_{10}H_{14}O_2$	1	195″	$C_{11}H_{15}O_3$	0,65	137′	$C_8H_9O_2$	0,25
149‴	$C_{11}H_{17}$	0,05	123	$C_8H_{11}O$	1	91	C_7H_7	1	151′	$C_{10}H_{15}O$	0,5	193	$C_{12}H_{17}O_2$	1	137″	$C_9H_{13}O$	0,5
123′	$C_8H_{11}O$	0,25	121	C_9H_{13}	1				151″	$C_{11}H_{19}$	0.5	192	$C_{12}H_{16}O_2$	1	137‴	$C_{10}H_{17}$	0,25
123″	C_9H_{15}	0,75	119	C_9H_{11}	1				123′	$C_8H_{11}O$	0,35	189	$C_{13}H_{17}O$	1	123	$C_8H_{11}O$	1
121′	C_8H_9O	0,1	100	$C_5H_8O_2$	1				123″	C_9H_{15}	0,65	183	$C_{10}H_{15}O_3$	1	109′	C_7H_9O	0,5
121″	C_9H_{13}	0,9	93	C_7H_9	1				119	C_9H_{11}	1	182	$C_{10}H_{14}O_3$	1	109″	C_8H_{13}	0,5
100	$C_5H_8O_2$	1	91	C_7H_7	1				100	$C_5H_8O_2$	1	177′	$C_{11}H_{13}O_2$	0.35			
93	C_7H_9	1										177″	$C_{12}H_{17}O$	0,65			

* The relative amount of the ion of the given composition in the measured peak.



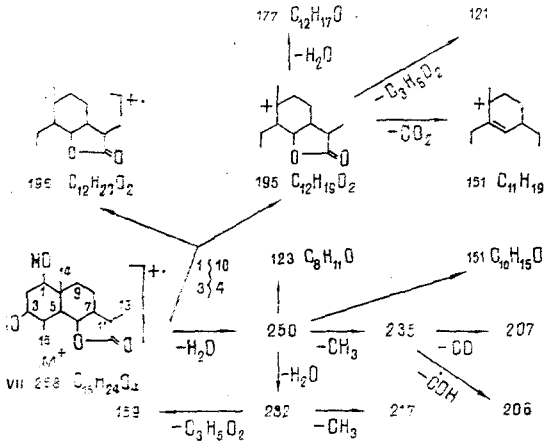
Scheme 2

of a ketene molecule from M^+. A process so uncharacteristic for the acetates of cyclic alcohols can be explained by the previous cleavage of the C_1–C_{10} bond. The $(M-CH_2CO)^+$ ions then form the same fragments as the molecular ions of the initial lactones (I-III). So far as concerns the ion $(M-AcOH)^+$, it decomposes with the elimination of H_2O, $\dot{C}H_3$, and CO.

We may note the existence of the main manner of fragmentation mentioned above in the case of the M^+ ions of (IV-VI), which leads to the ions with m/e 167 (IV, V) and 165 (VI), and also 142 (IV-VI). The composition of the latter was confirmed by measuring its accurate mass (Table 1) in the spectrum of artecalin acetate

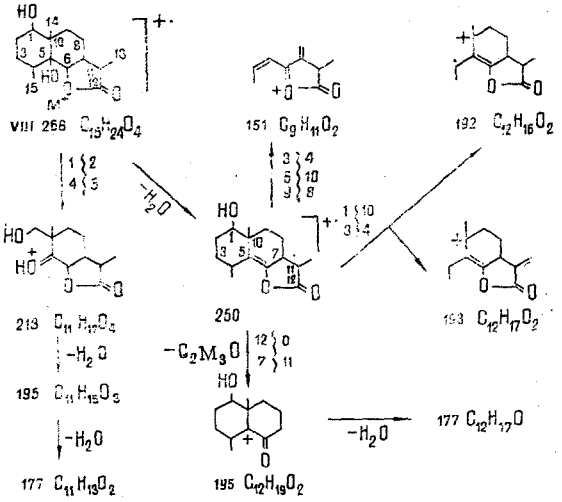
(VI). Subsequently, this fragment, losing a ketene molecule is converted into an ion with m/e 100. The ion with m/e 100 can be obtained directly from the ion $(M - CH_2CO)^+$.

Thus, the overall direction of fragmentation of the eudesmanolides with a C_1–OH group that have been considered consists in the cleavage of the C_1–C_{10} and C_4–C_5 bonds and the formation of ions including the elements of rings B and C. The presence of an additional OH group at C_3 (VII) and C_5 (VIII) somewhat changes the qualitative aspect of the decomposition of dihydroarabsin (VII) and dihydroarsubin (VIII). Thus, the process of eliminating a molecule of water with the formation of the ions $(M - H_2O)^+$ and $(M - 2H_2O)^+$ and the products of their decomposition (Schemes 3 and 4) is considerably intensified.



Scheme 3

On passing from one structure to another, a number of singularities of fragmentation appear. The peak of the ion with m/e 151 in the spectrum of (I) has a doublet nature (Table 1) and the main component, $C_9H_{11}O_2$, apparently arises from the elements of rings B and C, as is shown by the increase in the contribution of the ion with the composition $C_9H_9O_2$ in the group of isobaric ions with m/e 149 in the spectrum of artecalin (III). The ejection of a molecule of water and of the elements of rings B and C from M^+ of (I-III) in one stage leads to the appearance of an ion with the composition $C_8H_{11}O$ having m/e 123. In the spectrum of (III) it has a singlet nature, and in the case of arsanin (I) the ion with this composition is present in a proportion of 0.25 and is accompanied by the main ion C_9H_{15} (0.75) formed from the ion with m/e 167 (Scheme 2). Almost the same quantitative relationship is observed in the case of the ion with m/e 123 (Fig. 1) in the spectrum of dihydroarabsin (VII). Here the ion with the composition $C_8H_{11}O$ is obtained from $(M - H_2O)^+$ (Scheme 3). The next peaks in order of decreasing intensity in the spectrum of (VII) are those of ions with m/e 195 and 196. According to their compositions, they are formed by the elimination of the C_1–C_3 chain from the M^+ ion (Scheme 3). This process is activated by the presence of the two hydroxy groups. The same elements of the eudesmane skeleton are obviously present in the fragments with m/e 192 and 193 in the spectrum of dihydroarsubin (VIII), but they originate via the $(M - H_2O)^+$ ion (Scheme 4).



Scheme 4

We have detected the ejection of a C_4H_7 fragment by the M^+ ion (VIII), which is favored by the presence of the C_1-OH and C_5-OH groups. The subsequent elimination of a water molecule from $(M - C_4H_7)^+$ gives ions with m/e 195 and 177. However, both peaks of this mass are doublets the heavy components of which are formed from the $(M - H_2O)^+$ ion as the result of the breakdown of ring C (Scheme 4).

The ion with m/e 109 (Fig. 1) is also a doublet, with the components C_7H_9O (0.5) and C_8H_{13} (0.5). The formation of the former can be followed in Scheme 2, while the latter probably appears as the result of the one-stage decomposition of the M^+ ion of dihydroarsubin (VIII).

EXPERIMENTAL

The low-resolution mass spectra were obtained on a MKh-1303 instrument using a system of direct introduction of the sample, at a temperature of 110°C with an ionizing voltage of 40 V. The deutero analogs of compounds (I-III) were obtained by briefly heating solutions of the compounds in CD_3OD or $(C_2H_5)_2ND$ followed by the pumping off of the excess of solvent in the lock system of the mass spectrometer.

The elementary compositions of the ions were measured on a MKh-1310 mass spectrometer.

SUMMARY

The fragmentation of some C_1-OH eudesmanolides has been studied with the aid of an isotopic label and high-resolution mass spectrometry. It has been shown that the most characteristic fragmentation is that with the cleavage of the C_1-C_{10} and C_4-C_5 bonds. The sesquiterpene lactone arabsin has also been assigned to the C_1-OH eudesmanolides and this has been confirmed by its conversion into anhydroarabsin – an α,β-unsaturated ketone.

LITERATURE CITED

1. R. N. Sathe, G. H. Kulkarni, G. R. Kelkar, and K. G. Das, Org. Mass Spectrom., 2, 935 (1969).
2. D. G. B. Bookock and E. S. Waiht, Chem. Commun., 90 (1966).
3. N. Wasada, T. Tsuchiya, E. Yoshii, and E. Watanabe, Tetrahedron, 23, 4623 (1967).
4. T. C. Jain, J. E. McCloskey, and C. M. Banks, Org. Mass Spectrom., 5, 751 (1971).
5. R. N. Sathe, N. R. Deshpande, G. H. Kulkarni, G. R. Kelkar, and K. G. Das, Org. Mass Spectrom., 5, 197 (1971).
6. G. P. Moiseeva, B. Akyev, Sh. Z. Kasymov, and G. P. Sidyakin, Khim. Prir. Soedin., 167 (1973).
7. I. S. Akhmedov, Sh. Z. Kasymov, and G. P. Sidyakin, Khim. Prir. Soedin., 245 (1972).
8. V. A. Tarasov, Sh. Z. Kasymov, and G. P. Sidyakin, Khim. Prir. Soedin., 117 (1976).
9. V. A. Tarasov, Sh. Z. Kasymov, and G. P. Sidyakin, Khim. Prir. Soedin., 676 (1973).
10. Y. Koji and N. Kiyoshi, Chem. Pharm. Bull., 24, 2810 (1976).
11. H. Budzikiewicz, C. Djerassi, and D. H. Williams, Structure Elucidation of Natural Products by Mass Spectrometry, Holden-Day, San Francisco, Vol. 2 (1966), pp. 38 and 71.