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MASS SPECTROMETRY OF SESQUITERPENOIDS OF THE CAROTANE SERIES.
INFLUENCE OF VARIOUS METHODS OF IONIZATION ON THE FRAGMENTATION OF SESQUITERPENOLS

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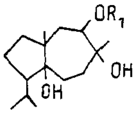
The mass spectra of five natural sesquiterpenols with various methods of ionization have been studied. A distinct direction of breakdown according to the alternative positions of the OH group at the C-4 or C-5 atom for the skeleton has been found. It has been established that the use of chemical ionization and of secondary-ion mass spectrometry raises the intensity of the molecular ions and increases specific directions of fragmentation.

Plants of the genus *Ferula* are rich in sesquiterpenoids of the carotane series [1]. There is no systematic information in the literature on the mass-spectral behavior of this type of compounds. They are characterized by a low intensity of M^+ in electron-impact spectra [1, 2], which complicates interpretation and structural investigations.

In view of this, we have studied the possibility of various methods of ionization for obtaining informative mass spectra of natural esterified carotanes. We used the methods of electron impact (EI), chemical ionization (CI), the chemical ionization of negative ions (CINI), and secondary-ion mass spectrometry (SIMS).

A series of carotanes differing by the nature and positions of the substituents in the skeleton was investigated: linkiol (I) [6], ferticin (II) [5], lapidin (III) [2], lapiferin (IV), and akiferin (V) [4].



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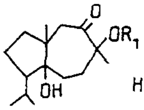

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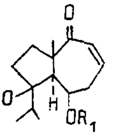

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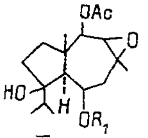

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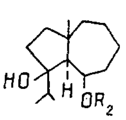

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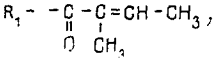
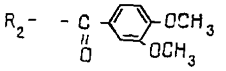


$R_1 - \; -\underset{\underset{O}{\|}}{C}-\underset{\underset{CH_3}{|}}{C}=CH-CH_3,$



The electron-impact spectra of this group of compounds showed a direction of fragmentation consisting in the competitive elimination of the substituents with retention of the carotane skeleton. In all cases the maximum ion corresponded to the acyl cation of the esterifying acid (m/z 83 and 165 for angelic and veratric acids, respectively).

The comparative analysis of the EI spectra of (I)-(V) also showed qualitative and quantitative differences (Table 1). There was a clear dependence of fragmentation on the position of the tertiary OH group. In the spectra of compounds (III)-(V), each having a hydroxyl at C-4, the peak, with variable intensity, of the $(M - 43)^+$ ion due to the splitting out of an isopropyl radical from M^+ was observed. This type of fragmentation is not characteristic for the M^+ ions of compounds (I) and (II)

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TABLE 1. Relative Intensities of the Ions (%) in the Mass Spectra of Compounds (I)-(V)

EI	I	338, M$^+$(0.2), 320(0.4), 238(M—AngOH)$^+$(3), . 220(2), 205(1.7), 195($C_{12}H_{19}O_2$)(1), 195($C_{13}H_{23}O$)(1), 194($C_{13}H_{22}O$)(2), 193($C_{13}H$[illegible]) (2), 167(21), 154(18), 151(15), 136(20), **83(100)**
	II	336 M$^+$(4), **319**(4), 253(M—Ang)$^+$(10), 236(M—AngOH)$^+$(25), 235(18), 194($C_{12}H_{18}O_2$)(7), 194($C_{13}H_{22}O$)(36), 193($C_{12}H_{17}O_2$)(6), 193($C_{13}H_{21}O$)(30), 151(18), 139(10), 108(15), 99(10), **83(100)**
	III	334, M$^+$(1), 291(M—43)$^+$(8), 234(M—AngOH)$^+$(18), 191(30), 185(5), 182(10), 165(12), 163(10), 145(12), 141(10), 109(10), **95(30), 83(100)**
	IV	394 M$^+$(0.1), 377(0.2), 351(M—43)$^+$(6), 294(M—AngOH)$^+$(10), 277(10), 251(18), 209(3), 191(25), 163(12), 152(10), 148(8), 126(10), **125(8), 83(100)**
	V	402 M$^+$(0.1), 385(0.2), 359(M—43)$^+$(1), 182(64), 177(30), **165(100)**, 159(20), 134(15), 132(8), 122(11), 121(10)
CI	I	339, MH$^+$(12), 338(10), 337(5), 321(10), 320(MH—H$_2$O)$^+$(10), 303(9), 221(MH—AngOH)$^+$(19), 203(15), 167(10), 154(21), 101(5), **83(100)**
	II	337 MH$^+$(4), 336(2), 335(2), 319(5), 237(MH—AngOH)$^+$(18), 221(15), 219(50), 194(10), 181(5), 179(6), 165(4), 163(3), 139(6), **101(24), 83(100)**
	III	335 MH$^+$(2), 317(4), 291(6), 263(9), **235(MH—AngOH)$^+$(100)**, 217(60), 191(15), 163(3), 161(5), 149(10), 121(20), **101(51)**, 83(29),
	IV	395 MH$^+$(2), 377(4), 351(10), 295(MH—AngOH)$^+$(41), 277(29), 251(21), 235(39), 217(78), 191(20), 189(18), 175(18), 152(20), 101(31), **83(100)**
	V	403 MH$^+$(1), 385(46), 359(2), 220(MH—VerOH)$^+$(27), 203(62), **182(VerOH)$^+$(100)**, 177(21), 165(64)
CINI	I	437(M+99)$^-$(28), **338 M$^-$**(12), 337(M—H)$^-$(25), 254(M—Ang)$^-$(30), **99(AngO$^-$)(100)**
	II	435(M+99)$^-$(16), 336 M$^-$(20), 235(2), 198(4), **99(AngO)$^-$(100)**
	III	433(M+99)$^-$(10), 334 M$^-$(8), 333(8), 332(15), 322(18), 250(17), 248(11), **234(M—AngOH)$^-$(100)**, 190(16), 99(23)
	IV	493(M+99)$^-$(16), 453(M+59)$^-$(28), 394 M$^-$(12), 393(10), 382(25), 294(4), 250(20), 234(15), 208(19), 190(64), **159(20)**, **99(100)**, 59(AcO$^-$)(95)
	V	402 M$^-$(20), 401(10), 387(40), 386(21), 363(8), 181(VerO)$^-$(41), **166(VerO$^{-\cdot}$ —CH$_3^{\cdot}$)$^-$(100)**
SIMS	I	339 (MH)$^+$(52), **321 (MH—H$_2$O)$^+$(100)**, 239 (MH—AngOH)$^+$(8), 221(49), 203(41), 167(20)
	II	**337 (MH)$^+$(100), 237** (MH—AngOH)$^+$(92), 219 (MH—AngOH—H$_2$O)$^+$(65)
	III	335(MH)$^+$(10), **317**(MH—H$_2$O)$^+$(4), **235(MH—AngOH)$^+$(100)**, 217(MH—AngOH—H$_2$O)(50)
	IV	395 (MH)$^+$(21), 377 (MH—H$_2$O)$^+$(41), 351(3), 295 (MH—AngOH)$^+$(31), 235 (MH—AngOH—AcOH)$^+$(43), **217(100)**
	V	403 (MH)$^+$(20), 385 (MH—H$_2$O)$^+$(42), **182** (VerOH)$^+$(25), 167(22), **165 (Ver)$^+$(100)**

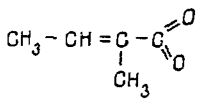
having an OH group at C-5. In their case, a AngOH molecule splits out with the formation of the (M — 100)+ ion. In the case of ferticin (II), this ion breaks down by cleavage of the C-9—C-10 chain in the form of the fragments C_2H_2O and C_2H_3O. The corresponding ions make up about 65% of the total height of the peaks with m/z 194 and 193. Minor components correspond to the elimination of C_3H_6 and C_3H_7 through the breakdown of the isopropyl substituent at C-4. The breakdown of the $(M - 100)^+$ ion in the spectrum of linkiol (I) leads to a triplet of ions with m/z 195-193. The composition of 50% of the ions with m/z 195 corresponds to the elimination of C_3H_7 and the other fragmentary ions arise by the elimination of C_2H_3O, C_2H_4O, C_2H_5O from the C-8 atom with the substituents attached to it.

As the result of the successive splitting out of the isopropyl radical and an angelic or veratric acid molecule from C-6, ions are formed with m/z 191 (in compound (III)) or 177 (in the spectrum of (V)). An ion with m/z 191 having an isomeric structure arises on the additional loss of AcOH in the case of lapiferin (IV). In the mass spectrum of akiferin (V), which contains veratric acid as the esterifying agent, the main peaks are also the ions of this acid and of the acyl cations with m/z 182 and 165. As the metastable defocussing (MD) spectrum of the ion with m/z 182 showed, it is formed either directly from M^+ of akiferin or from the product of the elimination of the isopropyl substituent in the form of C_3H_6.

The CI spectra showed an approximately tenfold increase in the stability of the MH^+ ions as compared with the M^+ ions in EI and a considerable increase in the contribution of fragmentation processes with the elimination of one molecule of water and of the corresponding acids (Table 1). The splitting out of a propane molecule from the MH^+ ions at the expense of the substituents at C-4 takes place only in the case of compounds with an OH group in the same position (compounds (III)-(V)) which serves as a characteristic distinguishing them from compounds (I) and (II) with an OH group at C-5.

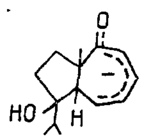
Of all the methods investigated, CI and SIMS showed the closest results, but in the case of SIMS the relative intensities of the protonated molecular ions MH^+ were far higher (see Table 1). The fragmentation pathways of the MH^+ ions of this series of compounds are also similar (see Table 1). An important distinguishing characteristic of the SIMS spectra is the complete suppression of the ejection of propane from MH^+, and also the absence of the ions $(M - VerOH)^+$ and $(M - VerOH - H_2O)^+$ in the spectra of compound (V) and of the ion $(M - AngOH - H_2O)^+$ for compound (IV). The SIMS spectra have the clearest lines of all the spectra obtained. In them, factors of the thermal decomposition of the sample are reduced practically to zero by the experimental conditions [7].

The CINI spectra of compounds (I)-(V) differ considerably from the EI and CI spectra. The intensities of the peaks of the M^- ions are lower than the peaks of the fragmentary ions (see Table 1). Moreover, in the case of compounds (I), (III), and (V), the M^- peaks are accompanied by the peaks of the $(M - 1^-)$ and $(M - 2)^-$ ions. A number of differences are also observed in the general form of the spectra (see Table 1); however, in all cases, with the exception of (III), the peaks of the $AngO^-$ and $VerO^-$ ions are predominant, which is connected with the gain in energy in the distribution of the excess negative charge on the carbonyl grouping conjugated with the double bond. In the case of compound (III), however, the maximum peak in the CINI spectrum is that of the $(M - AngOH)^-$ ion. Only in this compound of the given series is the carbonyl group at C-10 conjugated with the system of double bonds in the skeleton, which makes the formation of the $(M - AngOH)^-$ ion more favorable.



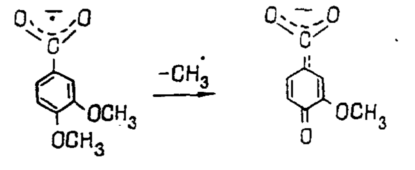
$CH_3-CH=C(CH_3)-C(=O)O^-$

R_1O^-, m/z 99(20%)



$(M-R_1OH)$, m/z 234(100%

It is interesting that in CI and SIMS spectra of this compound the $(MH - AngOH)^+$ ion is also the maximum ion, which indicates the predominant formation of an even-electron ion in these cases. The appearance in the CINI spectrum of a 100% ion with m/z 166 can be explained similarly. The latter is formed from the the veratric acid anion by following scheme



m/z 181(40%)

m/z 166(100%)

Another interesting observation in the CINI spectra is the formation of the cluster ions $(M + 59)^-$ and $(M + 99)^-$ in all cases in which the esterifying agents are acetic and angelic acids (see Table 1). The appearance of these ions does not depend on the nature of the reagent gas (CH_4, Ar) or on the recording conditions. The formation of clusters with molecules of the reagent gas has been reported in the literature [8], but it has not been possible to find an explanation of this fact. It may be assumed that the concentration of acetate and angelate anions in the plasma of the ion source is sufficient for the interaction of these ions with molecules of the substance; for example, $AngO^- + M \rightarrow [MAngO]^-$. However, this phenomenon has not been observed on working with other classes of compounds, such as acetates of sesquiterpene lactones of the pseudoguaiane series. The formation of clusters in the CI mass spectra of (V), where the esterifying agent is veratric acid, has not ben noted, either.

The explanation of this phenomenon requires an accumulation of experimental facts with a wider range of specimens.

EXPERIMENTAL

The electron-impact mass spectra were taken on a MKh 1310 instrument with a SVP-5 sample-inserting system at an ionizing voltage of 50 V, a collector current of 80 mA, and an accelerating voltage of 5 kV, the evaporator ampul being heated to 120-200°C, depending on the sample.

The SIMS mass spectra were obtained by Yu. M. Mil'grom on a MKh 1310 instrument with a secondary-ion source made by IAP RAN [Institute of Production Automation, Russian Academy of Sciences] (Saint Petersburg). Ionization was achieved with a beam of accelerated Cs ions having an energy of 7 keV and an accelerating voltage of 5 kV.

The CI and CINI mass spectra were taken on a Kratos MS-25RF instrument using a system for the direct insertion of the sample. The temperature of the ion source was 150°C, and the evaporating ampul was heated to 120-200°C, depending on the sample. A combined EI/CI ion source was used. The reagent gases were methane and argon. The pressure of the reagent gas was 0.5 mm Hg. The ionizing energy was 70 eV, the emission current 1 mA, and the accelerating voltage 4 kV.

REFERENCES

1. A. I. Saidkhodzhaev, Khim. Prir. Soedin., No. 4, 437 (1979).
2. L. A. Golovina and A. I. Saidkhodzhaev, Khim. Prir. Soedin., No. 3, 318 (1981).
3. L. A. Golovina, A. I. Saidkhodzhaev, and V. M. Malikov, Khim. Prir. Soedin., No. 3, 296 (1983).
4. A. Sh. Kadyrov, A. I. Saidkhodzhaev, G. K. Nikonov, and U. Rakhmankulov, Khim. Prir. Soedin., No. 2, 284 (1977).
5. M. K. Makhmulov, L. A. Golovina, B. Tashkhodzhaev, A. I. Saidkhodzhaev, M. R. Yagudaev, and V. M. Malikov, Khim. Prir. Soedin., No. 1, 68 (1989).
6. J. G. Luis, R. Esteves, I. L. Baez, and M. Rivero, **16**, No. 2, 265-267 (1977).
7. A. L. Burlingame, J. O. Whitney, and D. N. Russel, Anal. Chem., **56**, 417R-467R (1984).
8. R. C. Dougherty and I. D. Wander, Biomed. Mass Spectrom., **7**, 401 (1980).