MASS SPECTROMETRIC STUDY OF KAURENE DERIVATIVES

III. (−)-KAURENE AND METHYL ESTERS OF KAURENOIC ACIDS

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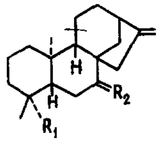
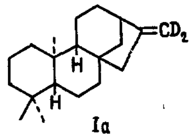
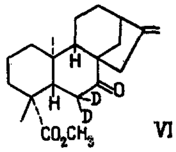
Diterpenoids of the kaurene group have been found in many natural sources [1]. They are of interest mainly as biogenetic precursors of the gibberellins. Our previous results [2] have shown that mass spectrometry may prove to be a promising method for analyzing the structure of kaurene derivatives. The following compounds have been studied:

	R_1	R_2
I.	CH_3	H_2
II.	CO_2H	H_2
III.	CO_2CH_3	H_2
IV.	CO_2CH_3	H,β-OH
V.	CO_2CH_3	H,α-OH
VI.	CO_2CH_3	O





Ia



VIa

We have obtained the mass spectra of compounds (II)-(VI) for the first time.

The mass spectrum of (−)-kaurene (I) (Fig. 1) is characterized by the presence of intense peaks of the molecular ion and of fragments formed by the ejection of 15, 43, and 59 mu (m/e 257, 229, and 213). In the mass spectrum of (Ia), analogous peaks are found at m/e 259, 229, and 213. Consequently, in the case of the M−43 and M−59 ions, C_{17}, C_{16}, and, probably, C_{15} are lost, and the elimination must take place in complex fashion with the migration of several hydrogen atoms. Therefore, it is to be expected that the presence of other functional groups in the molecule may substantially affect the intensities of the peaks of the (M−43) and (M−59) fragments.

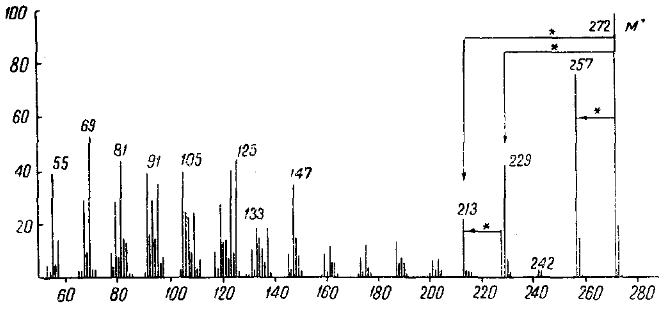


Fig. 1. Mass spectrum of (−)-kaurene.

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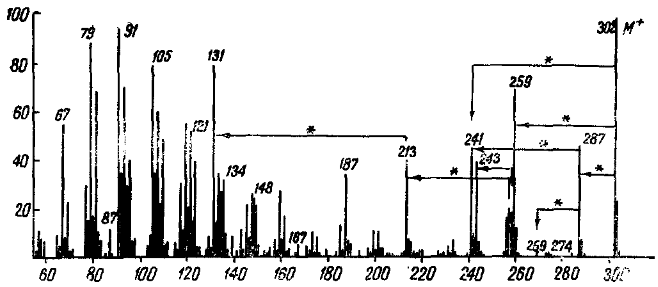


Fig. 2. Mass spectrum of (−)-kauren-4α-oic acid.

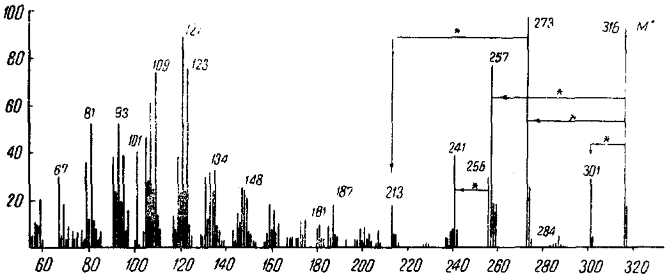
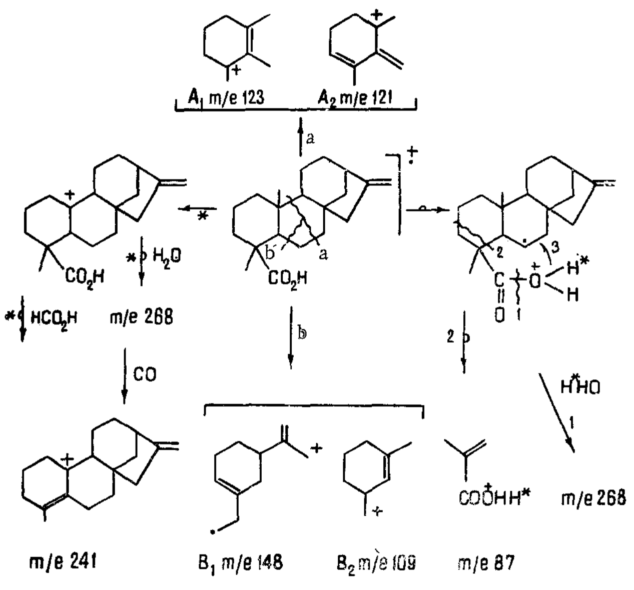


Fig. 3. Mass spectrum of the methyl ester of (−)-kauren-4α-oic acid.

When one of the geminal methyl groups was replaced by a carboxy group (II) or a methoxycarbonyl group (III), new peaks connected with the elimination of the substituent appeared in the mass spectrum (Figs. 2 and 3). The most important routes of fragmentation of these compounds and the possible composition of the ions are shown in Scheme 1 for kaurenoic acid (II).



Scheme 1

As can be seen, the splitting out of 43 and 59 mu forms strong peaks with m/e 259 and 243.

Cleavage of the C_9-C_{10}, C_5-C_6, and C_6-C_7 bonds with localization of the charge in the region of ring A or C leads to the appearance in the mass spectrum of a number of peaks in the range of medium mass numbers: m/e 109, 121, 123, and 148. The appearance of the corresponding fragments is apparently caused by the localization of the charge on the quaternary carbon atoms C_{10} and C_4 and in the region of the double bond. Thus, the formation of fragments A_1 and B_2 may be connected with the ejection of the substituent at C_4 as the result of the simple cleavage of the C_4-C_{19} bond, so that the positive charge is sta-

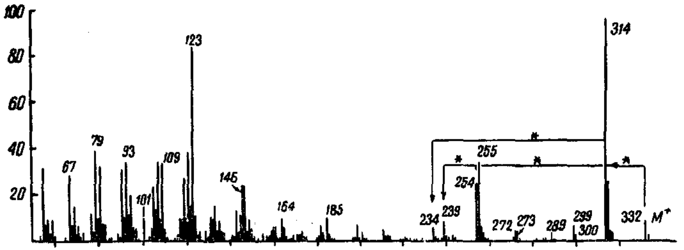


Fig. 4. Mass spectrum of the methyl ester of 7β-hydroxy-(−)-kauren-4α-oic acid.

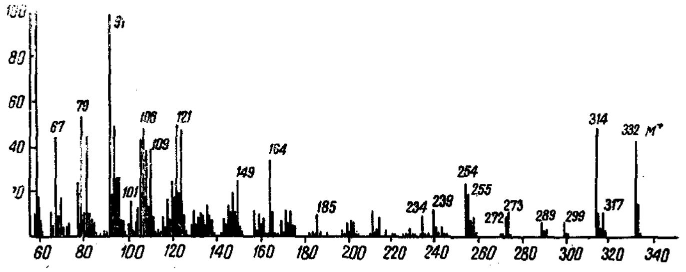


Fig. 5. Mass spectrum of the methyl ester of 7α-hydroxy-(−)-kauren-4α-oic acid.

bilized by a double bond and the appearance of B_1 by the ionization of the $C_{16}-C_{17}$ double bond with subsequent cleavages of the allyl bonds. All these peaks are also present in the mass spectra of the kauran-16-ols [3], where their appearance from a particular part of the molecule was confirmed by the spectra of the deutero analogs.

Analogs of the fragment with m/e 87 [shifted to m/e 101 in the spectra of (III)-(VI)], which are also present in the spectrum of 16α-hydroxy-(−)-kaurenoic acid, are absent from the spectra of the corresponding aldehyde and alcohol [3]. The formation of this fragment, it appears, is best regarded as taking place from M^+, in which the carboxy group is protonated by the hydrogen at C_6 or C_1, which is available for migration [4]. Apart from routes 1 and 2 (see Scheme 1), the further conversion of such a M^+ may consist in the back-migration of one of the hydrogen atoms. In actual fact, in the mass spectrum of the OD analog of the acid the peaks with m/e 247 ($M-HCO_2D$), 241 ($M-CH_3-HCO_2D$), 213 ($M-C_3H_7-HCO_2D$), 269 ($M-CH_3-HDO$), and 88 are partially shifted to m/e 248, 242, 214, and 87, respectively. A similar exchange of hydrogen between the carboxy group and the hydrocarbon skeleton has been observed for carboxylic acids of the adamantane series [5].

The mass spectra of esters of the epimeric 7-hydroxykaurenoic acids (IV) and (V) (Figs. 4 and 5) are similar to those of the unsubstituted acid and ester. The differences are due mainly to the presence of a series of peaks in the spectra of the hydroxy esters (IV) and (V) due to the splitting out of H_2O.

$$m/e\ 332\ (M^+) \xrightarrow{\overset{18}{\circ}} m/e\ 314 \xrightarrow{59} m/e\ 255;$$

$$m/e\ 234 \leftarrow m/e\ 314 \xrightarrow{\overset{60}{\circ}} m/e\ 254 \xrightarrow{15} m/e\ 239.$$

In this case, the splitting out of 43 and 15 mu is of secondary importance.

There are considerable differences in the intensities of the dehydration peaks for the epimers (ease of dehydration),

$$\left[\frac{I\,(M-18)^+}{I\,(M)^+}\right]_\beta \Big/ \left[\frac{I\,(M-18)^+}{I\,(M)^+}\right]_\alpha \simeq 11,$$

which prove to have a considerable influence on other routes of fragmentation also. Thus, the peak with m/e 164 [B_1 in (II)], containing a hydroxy group (shifted to m/e 165 in the mass spectrum of the OD analog) is far stronger in the mass spectrum of the α epimer, while the opposite applies to the m/e 146 peak.

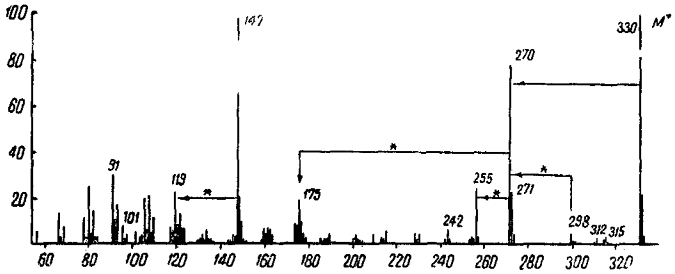
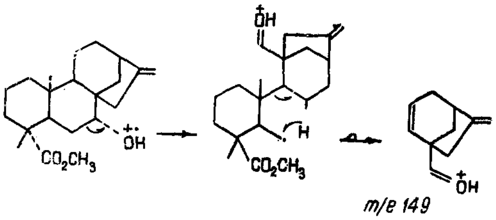


Fig. 6. Mass spectrum of the methyl ester of 7-keto-(—)-kauren-4α-oic acid.

The formation of a fragment with m/e 149 in the α epimer (m/e 150 in the OD analog) may be explained by α-cleavage with the localization of the charge on the hydroxy oxygen.



Scheme 2

This route of fragmentation becomes dominating in the methyl ester of 7-ketokaurenoic acid (VI). The M^+ peak and that of the characteristic fragment with m/e 147 [m/e 147 in (VIa)] are the maximum peaks in the spectrum (Fig. 6).

The splitting out of a methoxycarbonyl group with the successive or simultaneous elimination of 32 and 28 mu also leads to a strong peak with m/e 270 while, as follows from the mass spectrum of (VIa), the total contribution of the α-hydrogens to the rearrangement amounts to about 38%. The splitting out of 43 mu, which is characteristic for the ester of the unsubstituted acid (III) and, to a smaller extent, for the 7-hydroxy esters (IV) and (V), is not observed in this case.

Thus, the mass spectra of the 7-substituted methyl esters (V) and (VI) are characterized by the presence of fragments resulting from α-cleavage with m/e 149 (V) and 147 (VI), which may be useful for determining the positions of substituents in isomers. The stereochemical differences are sufficient for the identification of the epimers (IV) and (V) from their mass spectra.

EXPERIMENTAL

The mass spectra were taken on a standard MKh-1303 instrument fitted with a completely metallic system for introducing the sample directly into the ion source at an energy of the ionizing electrons of 45 eV.

(—)-Kaurene (I) was obtained from the culture liquid of F. moniliforme, mp 49.5-50.5°C, $[\alpha]_D -78°$. The oxidation of (I) with a mixture of OsO_4 and $NaIO_4$ in 90% aqueous dimethylformamide (20°C, 4 h) gave 16-oxo-17-nor-(—)-kaurene with mp 116-119°C. The latter was converted by a method similar to that described previously into 17-D_2-kaurene (Ia) by the Wittig reaction with CD_3PPh_3.

(—)-Kauren-4α-oic acid (II) and its methyl ester (III) were kindly given to us by Prof. P. R. Jefferies (Australia).

The methyl ester of 7-oxo-(—)-kaurenoic acid (VI) with mp 111-114°C was prepared by the hydrogenolysis of 7β-hydroxykaurenolide by a known method; the epimeric hydroxy esters (IV) and (V) were isolated as minor components in the chromatographic purification of (VI).

The 6-D_2-analog of (VI) (VIa), with mp 109-112°C was obtained by boiling (VI) in a mixture of D_2O and absolute dioxane (15 : 85) in the presence of traces of NaOD.

SUMMARY

For subsequent analytical use of the laws of fragmentation, the mass spectra of (−)-kaurene (I) and its derivatives (II)-(VI) have been studied.

LITERATURE CITED

1. J. R. Hanson, The Tetracyclic Diterpenes, Pergamon Press, Oxford (1968).
2. E. P. Serebryakov, N. S. Kobrina, A. B. Simolin, and V. F. Kucherov, Chem. Ind. (London), 1968, 1770.
3. A. I. Kalinovsky, E. P. Serebryakov, B. M. Zolotarev, A. V. Simolin, V. F. Kucherov, and O. S. Chizhov, Org. Mass Spectrom., 3, 1393 (1970).
4. C. R. Enzell and I. Wahlberg, Acta Chem. Scand., 23, 871 (1969).
5. A. G. Yurchenko, F. N. Stepanov, S. S. Isaeva, B. M. Zolotarev, V. I. Kadentsev, and O. S. Chizhov, Org. Mass Spectrom., 3, 1401 (1970).