cosides 3-O-[O-β-D-glucopyranosyl-(1 → 2)-β-D-glucopyranosyl]oleanolic acid and 3-O-[O-β-D-glucopyranosyl-(1 → 2)-β-D-glucopyranosyl]hederagenin [6] with elution by solvent systems 2, 4, and 6, and also mixtures of 3-O-α-L-arabinosyl-28-O-[O-α-L-rhamnopyranosyl-(1 → 4)-O-β-D-glucopyranosyl-(1 → 5)-β-D-glucopyranosyl]hederagenin and 3-O-[O-α-L-rhamnopyranosyl-(1 → 2)-α-L-arabinopyranosyl-28-O-[O-α-L-rhamnopyranosyl-(1 → 4)-O-β-D-glucopyranosyl-(1 → 6)-O-β-D-glucopyranosyl]hederagenin with elution by solvent systems 1, 3, and 5. Samples of the eluates were analyzed by TLC. The chromatographic characteristics of the alkylated silica gels and the amounts of modifying agents remained stable over a year.

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ALKALOIDS OF Aconitum coreanum.
III. 13-ACETYL-14-HYDROXY-2-ISOBUTYRYLHETISINE N-OXIDE

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UDC 547.944/945+548.737

It has been established by the x-ray structural method that a new alkaloid isolated from the epigeal part of *Aconitum coreanum* has the structure of 13-acetyl-14-hydroxy-2-isobutyrylhetisine N-oxide. This is the first time that a N-oxide has been isolated among the hetisine alkaloids.

The isolation from the epigeal part of *Aconitum coreanum* (Levl) Rapaics of four alkaloids belonging to the hetisine and atisine types has been reported previously [1, 2]. Continuing investigation of the alkaloids of this plant from the mother liquors before the isolation of 14-hydroxy-2-isobutyrylhetisine (Guan-Fu base Z) we obtained a crystalline mixture of perchlorates which, by the usual treatment, was converted into a mixture of bases. The column chromatography of this mixture gave a new base with mp 240-242°C, M^+ 473, which proved to be 13-acetyl-14-hydroxy-2-isobutyrylhetisine N-oxide. Its perchlorate had mp 285-288°C (from ethanol). The IR spectrum of the perchlorate showed the absorption bands of hydroxy groups (3500, 3400 cm^{-1}), of an ester carbonyl (1740, 1720 cm^{-1}), and of a double bond (1660, 890 cm^{-1}). According to its PMR spectrum, the base contained an exomethylene group (broadened singlet at 4.90 and 4.99 ppm), one acetoxy group (singlet, 3H at 2.04 ppm), an isobutyryloxy group (two doublets, 3 H each, at 1.24 and 1.15 ppm, J = 4 Hz) and a methyl group (singlet, 3 H at 1.20 ppm).

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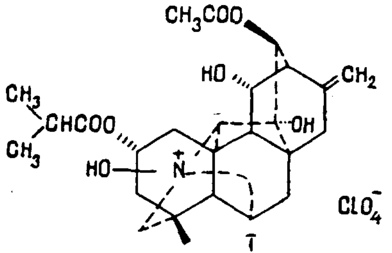
To establish unambiguously the structure of the alkaloid that had been isolated and to solve all the stereochemical questions, an x-ray structural analysis has been made of a crystal of its perchlorate (I), the results of which have enabled the structure of the alkaloid to be determined:



I

The x-ray structural analysis showed that the compound isolated was a N-oxide (from electron density values and the O7–$\overset{+}{N}$ distance of 1.39 Å). The mass spectrum agreed well with the N-oxide structure of (I). In the mass spectrum of (I) with M^+ 473 there was a triplet, characteristic for N-oxides, of the peaks of ions at m/z 457 (M – 16) (28%), 456 (M – 17) (14%), and 455 (M – 18) (15%) [3]. The strongest ion peaks in the spectrum of (I), with m/z 430 (91%) and 414 (100%), were formed as the result of the splitting out of 43 m.u. from the molecular ion and the M – 16 ion, respectively. This is the first time that an alkaloid in the form of a N-oxide has been isolated among derivatives of the hetisine series.

The structure of the cation (I) in a projection on the (001) crystallographic plane is shown in Fig. 1. The molecule of (I) contains a rigid 3-dimensional hetisine skeleton of 10 rings with the following substituents: two hydroxyls (11α and 14α), a methyl on a tertiary carbon (4β), a ring methylene (16), and acetoxy (13β) and isobutyryloxy (2α) groups. The conformations of the rings can be judged from the determination of the torsion angles (Table 1). The six-membered rings A and B have a chair configuration (ring B slightly distorted). Rings C, D, and E form a bicyclo[2.2.2]octane system in which they each have the boat conformation with appreciable distortions of rings C and D. These distortions are apparently connected with the fact that (I) has a rigid skeleton. The five-membered rings F, G, and H have the envelope conformation: the C8 atom departs from the plane of the C9, C10, C14, and C20 atoms (±0.03 Å) by 0.76 Å, the C5, C10, C20, and N atoms lie in one plane and the C6 atom departs from it by 0.88 Å and from the plane of the C4, C5, C19, and N atoms (±0.02 A) by 0.84 Å. The six-membered heterocycles K and L have the boat and chair conformations, respectively. The linkages of the rings are as follows: A/B – trans; A/H – cis; B/C – trans; B/H – trans; C/F – cis; D/F – cis; B/K – trans; and F/K – cis. On the whole,

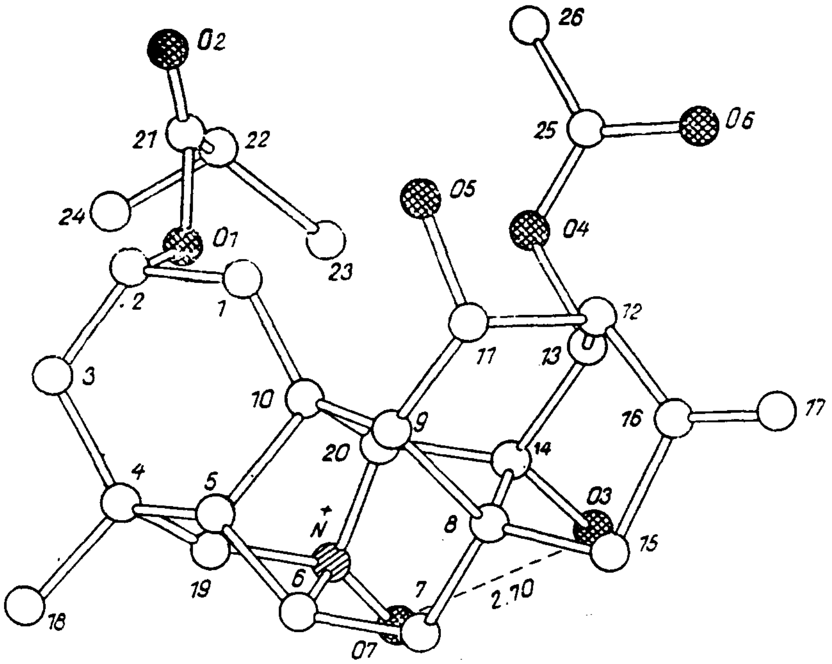


TABLE 1. Endocyclic Torsion Angles (φ, deg) in the Structure of (II)

Angle	φ	Angle	φ	Angle	φ
Ring *A*		Ring *D*		Ring *K*	
C10-C1-C2-C3	51	C11-C9-C8-C14	—81	C20-C10-C5-C4	—68
C1-C2-C3-C4	—51	C9-C8-C14-C13	69	C10-C5-C4-C18	69
C2-C3-C4-C5	54	C8-C14-C13-C12	—5,9	C5-C4-C18-N38	2
C3-C4-C5-C10	-54	C14-C13-C12-C11	—49	C4-C18-N38-C20	—74
C4-C5-C10-C1	54	C13-C12-C11-C9	38	C18-N38-C20-C10	77
C5-C10-C1-C2	-54	C12-C11-C9-C8	27	N38-C20-C10-C5	—3
Ring *B*		Ring *E*		Ring *F*	
C10-C5-C6-C7	58	C12-C13-C14-C8	—6	C10-C20-C14-C8	32
C5-C6-C7-C8	—48	C13-C14-C8-C15	—55	C20-C14-C8-C9	—50
C6-C7-C8-C9	50	C14-C8-C15-C16	50	C14-C8-C9-C10	45
C7-C8-C9-C10	-68	C8-C15-C16-C12	17	C8-C9-C10-C20	—26
C8-C9-C10-C5	82	C16-C12-C13-C14	67	C9-C10-C20-C14	—3
C9-C10-C5-C6	—73	C15-C16-C12-C13	—74		
Ring *C*		Ring *L*		Ring *G*	
C16-C12-C11-C9	—73	C14-C20-N38-C6	72	C6-C5-C10-C20	40
C12-C11-C9-C8	27	C20-N38-C6-C7	—66	C5-C10-C20-N38	—3
C11-C9-C8-C15	40	N38-C6-C7-C8	61	C10-C20-N38-C6	-32
C9-C8-C15-C16	—64	C6-C7-C8-C14	—58	C20-N38-C6-C5	57
C8-C15-C16-C12	17	C7-C8-C14-C20	64	N38-C6-C5-C10	—59
C15-C16-C12-C11	46	C8-C14-C20-N38	—73	Ring *H*	
				C4-C5-C6-N38	54
				C5-C6-N38-C18	—54
				C6-N38-C18-C4	31
				N38-C18-C4-C5	2
				C18-C4-C5-C6	—36

TABLE 2. Bond Lengths d (Å) and Valence Angles ω (deg) in the Structure of (II)

Bond	*d*	Bond	*d*	Angle	ω	Angle	ω	Angle	ω
C1—C2	1,61	C12—C16	1,50	C2C1C10	112	C8C9C11	104	C12C16C15	112
C1—C10	1,61	C13—O4	1,41	C1C2C3	109	C10C9C11	123	C12C16C17	127
C2—C3	1,50	C14—C13	1,61	C1C2O1	112	C1C10C5	111	C15C16C17	118
C2—O1	1,40	C14—O3	1,43	C3C2O1	109	C1C10C9	115	C4C18N	101
C3—C4	1,53	C14—C20	1,56	C2C3C4	115	C1C10C20	115	C10C20C14	101
C4—C5	1,54	C15—C16	1,56	C3C4C5	113	C5C10C9	104	C10C20N	102
C4—C19*	1,63	C16—C17	1,31	C3C4C19	114	C5C10C20	103	C14C20N	107
C4—C18*	1,58	C19—N	1,50	C3C4C18	108	C9C10C20	108	O1C21O2	119
C5—C6	1,48	C20—N	1,54	C5C4C19	102	C9C11C12	113	C22C21O1	113
C5—C10	1,55	C21—O1	1,33	C5C4C19	113	C9C11O5	116	C22C21O2	128
C6—C7	1,55	C21—O2	1,20	C18C4C19	106	C12C11O5	105	C21C22C23	107
C6—N	1,54	C21—C22	1,55	C4C5C6	103	C11C12C16	109	C21C22C24	108
C7—C8	1,54	C22—C23	1,46	C4C5C10	110	C11C12C13	114	C23C22C24	113
C8—C9	1,52	C22—C24	1,58	C6C5C10	99	C16C12C13	100	C26C25O6	122
C8—C14	1,58	C25 - C25	1,50	C5C6C7	119	C12C13C14	109	O4C25O6	119
C8—C15	1,52	C25—O4	1,30	C5C6N	96	C12C13O4	110	C26C25O4	117
C9—C10	1,54	C25—O6	1,29	C7C6N	111	C14C13O4	109	C2O1C21	119
C9—C11	1,57	N—O7	1,39	C6C7C8	108	C8C14C13	108	C13O4C25	120
C10 C20	1,57	C1 - O8	1,30	C7C8C9	108	C8C14C20	105	C6NC20	100
C11—C12	1,46	C1 O9	1,28	C7C8C15	109	C13C14O3	107	C6NC18	105
C11—O5	1,48	C1—O10	1,46	C7C8C14	109	C20C14O3	114	C6NO7	120
C12—C13	1,56	C1—O11	1,44	C9C8C15	117	C13C14C20	112	C20NC18	108
				C9C8C14	100	C8C15C16	105	C20NO7	116
				C8C9C10	103	C18NO7	106		

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*In view of the statement in the text concerning the length of the C4-C18 bond and the order in which they are given, it seems possible that "C4-C19" and "C4-C18" have been interchanged here — Translator.

the conformations and linkages of the main rings of the hetisine core of the molecule of (I) agree completely with those observed in talatasine [4].

Deviations from the standard values are observed in the bond lengths (Table 2): the ordinary bonds C1—C2, C1—C10, and C4—C18 are appreciably lengthened (to 1.63 Å) and so is the C25—O6 double bond (to 1.29 Å), while the C11—C12 and C5—C6 ordinary bonds are shortened (1.46 and 1.48 Å, respectively). These deviations are due to experimental errors (a limited set of structural amplitudes). However, on the whole, the lengths of the majority of the bonds agree with the standard lengths to within 3σ [5].

The following values of the valence angles are observed in the molecule of (I) (Table 2): in the five-membered rings, 97-107°, and in the six-membered rings, 99-119°. This variation in the values of the angles is connected with the strain in the molecule. The increase in one of the angles to 128° for the sp^2-hybridized C21 atom of the isobutyryloxy group is normal [6, 7].

The mutual positions of the OH and O3H hydroxy groups in the cation of (II) favor the formation of an intramolecular H-bond of the O—H···O type favored by the O7···O3 distance of 2.70 Å.

In the crystal structure of (I) an intercationic H-bond of the O—H···O type between the O5 atom of the hydroxy group of the initial cation and the O6 atom of the acetoxy group of a cation derived by a 2_1 axis [x, 3/4, 0] is observed. In addition, there is a H bond between the O3 atom of the cation and the O9 atom of the anion (distance 2.72 Å).

EXPERIMENTAL

IR spectra were obtained on a UR-20 spectrometer using tablets with KBr, mass spectra on a MKh-1310 instrument, and the PMR spectrum on a BS-567 A spectrometer (working frequency 100 MHz, δ scale, solvent CD_3OD, standard – HMDS). Chromatographic monitoring was carried out by TLC (LSL 5/40 alumina, neutral, Czechoslovakia) in the solvent systems chloroform—methanol (25:1) and (20:1). The isolation and separation of the alkaloids has been described in [1]. From the oily hexane—ether fraction obtained before the elution of the Guan-Fu base Z a crystalline mixture of perchlorates was isolated which was separated and crystallized from alcohol. The alcoholic mother liquors remaining after the purification of the perchlorate were converted into the base, which was rechromatographed on alumina. Hexane eluates yielded (I) with mp 240-242°C; its perchlorate (II) had mp 285-288°C (from ethanol).

Mass spectrum (m/z, %): 473(M^+)(41), 457$(M - 16)^+$(28), 430$(M - 43)^+$(91), 414 $(M - 16 - 43)^+$(100), 398(41), 384(18), 326(20).

The space group and parameters of the elementary cell were established by the photo method. The parameters were refined on Syntex $P2_1$ diffractometer using CuK_α radiation: a = 9.849, b = 17.699 Å, c = 15.473 Å; d_{calc} = 1.424 g/cm³. Space group $P2_12_12_1$, Z = 4. In the calculations we used a limited set of structural amplitudes: 929 for the 39 nonhydrogen atoms (which was apparently due to the low quality of the crystal). The structure was interpreted by the direct method using the Rentgen-75 program [8] in the automatic regime and was refined by the method of least squares. The refinement of positions of the nonhydrogen atoms was completed at the stage of isotropic approximation, and in the final refinement the H atoms were included with fixed position and temperature parameters to R = 0.087. The coordinates of the C, O, and N atoms are given in Table 3.

TABLE 3. Coordinates (× 10^4) of the Nonhydrogen Atoms in the Structure of (II)

Atom	x/a	y/b	z/c	Atom	x/a	y/b	z/c
C1	437 (2)	178 (1)	598 (1)	C21	475 (2)	260 (9)	793 (1)
C2	547 (3)	186 (1)	675 (1)	C22	450 (4)	255 (1)	892 (2)
C3	640 (2)	119 (1)	673 (2)	C23	330 (5)	208 (2)	905 (2)
C4	571 (2)	041 (1)	671 (1)	C24	583 (4)	223 (2)	936 (2)
C5	468 (2)	032 (9)	596 (1)	C25	041 (2)	260 (1)	675 (2)
C6	380 (2)	—031 (1)	630 (1)	C26	107 (3)	320 (1)	728 (2)
C7	250 (2)	—051 (1)	572 (1)	O1	490 (1)	192 (6)	756 (7)
C8	172 (2)	023 (1)	555 (1)	O2	498 (1)	316 (6)	751 (8)
C9	270 (2)	081 (9)	519 (8)	O3	054 (1)	012 (6)	695 (7)
C10	362 (2)	097 (9)	598 (1)	O4	111 (1)	197 (5)	663 (7)
C11	175 (2)	144 (1)	479 (1)	O5	230 (1)	223 (5)	485 (7)
C12	043 (3)	147 (1)	522 (1)	O6	—086 (1)	261 (7)	655 (9)
C13	049 (2)	134 (1)	622 (1)	O7	268 (1)	−036 (7)	773 (7)
C14	137 (2)	060 (9)	642 (1)	O8	−100 (3)	104 (1)	967 (1)
C15	042 (2)	005 (1)	498 (1)	O9	−121 (3)	064 (2)	828 (2)
C16	—042 (3)	080 (1)	495 (1)	O10	—057 (4)	180 (2)	849 (3)
C17	−156 (2)	080 (1)	453 (1)	O11	084 (3)	088 (1)	886 (2)
C18	686 (2)	—021 (1)	670 (1)	N	342 (1)	050 (6)	713 (8)
C19	476 (2)	023 (9)	755 (1)	Cl	−060 (8)	103 (4)	885 (5)
C20	278 (2)	080 (9)	682 (1)				

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ALKALOIDS OF Aconitum coreanum.
IV. 14-HYDROXY-2-ISOBUTYRYLHETISINE N-OXIDE

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A new alkaloid has been isolated from the epigeal part of Aconitum coreanum (Levl.) Rapaics, for which the structure of 14-hydroxy-2-isobutyrylhetisine N-oxide has been established on the basis of spectral characteristics and a chemical transformation.

Aconitum coreanum (Levl.) Rapaics grows in the south of Maritime Territory and is known as a poisonous plant [1] possessing antibacterial activity [2]. We have reported the isolation of a series of diterpene alkaloids from this plant previously [3].

Continuing our investigation, we have isolated a new optically active base crystallizing in the form of needles with mp 317-319°C, composition $C_{24}H_{33}NO_6$ (I). Its IR spectrum showed the absorption bands of hydroxy (3600-3200 cm^{-1}), ester carbonyl (1730 cm^{-1}), and exomethylene (1680 cm^{-1}) groups. Its PMR spectrum contained the signals from tertiary methyl (δ 1.15 ppm, 3 H, singlet), gem-dimethyl (1.16 ppm, 6 H, doublet, J = 6 Hz), and exomethylene (4.75 and 4.65 ppm; broadened singlets, 1 H each) groups. These facts permitted the conclusion that (I) belonged to the C_{20}-diterpene alkaloids with an isobutyryl substituent.

Base (I) differed in composition from the 14-hydroxy-2-isobutyrylhetisine (II) isolated from this plant [3] (the so-called Guan-Fu base Z [4]) by an oxygen atom. A comparison of the mass spectra of (I) and (II) showed that in (I), together with the M^+, M − 17, M − 28, M − 45, M − 56, and M − 87 peaks characteristic for (II) [5], there were the peaks of the ions M − 16, M − 18, M − 16 − 17, M − 16 − 28, M − 16 − 45, M − 15 − 56, and M − 16 − 87, which gave grounds for the assumption that (I) was the N-oxide of an isobutyryl derivative of 14-hydroxyhetisine.

According to TLC results, the alkaloid did not possess the high polarity characteristic of N-oxides. Furthermore, it did not dissolve in water, was sparingly soluble in chloroform and moderately in ethanol and methanol, and crystallized readily from the latter and also when water was added to its dilute ethanolic solutions. The presence of a N→O group and the position of the isobutyryl substituent in (I) were established by ^{13}C NMR spectroscopy.

The results of a comparison of the ^{13}C NMR spectra of (I) and (II) (Table 1) showed

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