LITERATURE CITED

1. G. Cimino, R. Morrone, and G. Sodano, Tetrahedron Lett., 23, 4139 (1982).
2. P. F. Vlad, N. D. Ungur, and M. N. Koltsa, Tetrahedron, 39, 3957 (1983).
3. P. F. Vlad and N. D. Ungur, Khim. Prir. Soedin., 725 (1984).
4. D. S. De Mizanda, G. Brendolan, P. M. Imamura, M. G. Sierra, A. J. Mazsaioli, and E. A. Ruveda, J. Org. Chem., 46, 4851 (1981).
5. J. C. Collins, W. W. Hess, and F. J. Frank, Tetrahedron Lett., 3363 (1968).
6. K. Omura and D. Swern, Tetrahedron, 34, 1351 (1978).
7. G. Cimino, D. De Rosa, S. De Stefano, and L. Minale, Tetrahedron, 30, 645 (1974).

ISOMERIZATION EQUILIBRIUM OF THE p-MENTHADIENES IN THE VAPOR PHASE

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The isomerization equilibrium between nine p-menthadienes has been studied in the vapor phase at 250°C and their equilibrium ratios have been determined. A method for the quantitative GLC analysis of mixtures of isomeric p-menthadienes has been developed.

The contact of α-pinene with catalysis of the acidic type leads to the formation of, with other products, dipentene and p-menthadienes isomeric with it [1]. The mutual transformations of the p-menthadienes have been studied repeatedly [2, 3], but the equilibrium concentrations for the liquid phase are given in only two publications [4, 5]. In [4], the ratio of three isomers on potassium isobutanolate in dimethyl sulfoxide (50°C) is evaluated. Bates et al. [5] achieved equilibria of six p-menthadienes at 200°C on potassium tert-butanolate in tert-butanol and of four compounds at 67°C in the presence of dilute sulfuric acid. Equilibrium isomerization in the vapor phase on acidic catalysts has not been performed because of the considerable development of aromatization and polymerization processes.

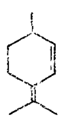
We have studied the equilibrium of the isomerization of α-terpinene (I), α-phellandrene (II), mentha-2,4-diene (III), γ-terpinene (IV), isoterpinolene (V), mentha-3,8-diene (VI), β-phellandrene (VII), terpinolene (VIII), and dipentene (IX) in the vapor phase at 250°C on alumina.


I


II

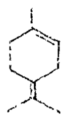

III

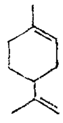

IV


V


VI


VII


VIII


IX

The experiments were performed by the pulse method in a microreactor included in the gas line of a chromatograph. This permitted the reaction to be performed in an inert oxygen-free medium with strong dilution of the sample with carrier gas (argon) and thus enabled the polymerization of the products to be avoided to a considerable degree. The time of contact of the substances with the catalyst was regulated by the length of the catalyst bed in a tubular reactor with a constant space velocity of the carrier gas. The conditions of the experiment excluded the establishment of a chromatographic regime of the working of the microreactor [6].

The equilibrium ratios were reached from the direction of different p-menthadienes and from α- and β-pinenes (XI and XII) (Table 1), regardless of the amount of p-cymene in the

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TABLE 1. Results of the Experiments on the Isomerization of the p-Menthadienes at 250°C

Initial compound	Volume of catalyst, mm^3	No. of experiments	Composition of the equilibrium mixture, % molar									X is %-molar of the sum of the dienes
			I	II	III	IV	V	VI	VII	VIII	IX	
I	90–630	4	43,7±0,9	4,2±0,3	4,7±0,6	15,8±0,6	21,6±1,0	4,5±0,2	2,0±0,1	2,5±0,5	1,0±0,2	20–30
V	160–630	2	44,6±0,4	3,1±0,1	4,7±0,2	16,5±0,1	21,7±0,1	4,5±0,1	1,2±0,0	2,1±0,1	1,6±0,5	20–30
VII	90–630	4	44,9±0,7	3,1±0,1	4,6±0,3	16,4±0,4	21,6±0,5	4,4±0,1	1,2+0,1	2,6±0,4	1,2±0,4	8–30
VIII	100–630	4	43,6±0,8	3,0±0,2	4,7±0,3	17,0±0,4	22,5±0,7	4,6±0,3	1,2±0,1	2,4±0,2	1,0±0,1	6–20
IX	160–630	3	44,2±0,7	3,2±0,0	4,6±0,1	17,0±0,9	22,3±0,3	4,4±0,2	1,2±0,4	2,2±0,1	0,9±0,1	10–30
XI	440–900	2	42,1±0,2	4,4±0,9	4,8±0,[illegible]	16,6±0,3	21,4±0,1	4,3±0,4	1,8±0,6	3,3±0,8	1,3±0,7	6–8
XII	900	1	42,8	3,5	5,0	16,7	23,9	4,4	1,4	1,6	0,7	14
Mean			43,9±1,0	3,4±0,5	4,7±0,3	16,5±0,5	22,0±0,7	4,5±0,2	1,4±0,3	2,5±0,4	1,1±0,3	—

TABLE 2. Equilibrium Constants of the p-Menthadiene Isomerization Reactions

Reaction	Present work	[5]		[4]
	250°	200°	67°	50°
I ⇄ II	0,077	—	—	—
I ⇄ III	0,107	0,035	—	—
I ⇄ IV	0,376	0,346	0,259	0,20
I ⇄ V	0,501	0,672	0,559	0,60
I ⇄ VI	0,103	0,115	0,058	—
I ⇄ VII	0,032	—	—	—
I ⇄ VIII	0,057	0,035	—	—
I ⇄ IX	0,025	—	—	—

isomeric mixtures, the amount of which, depending on the time of the contact of the substances with the catalyst and the initial compounds, ranged between 6 and 30 mol. %, calculated on the mixture of dienes. At the same time, even in experiments with a high degree of conversion such a small amount of p-menthenes and p-menthanes was obtained (1-2%) that the formation of p-cymene was not included in the scheme of irreversible catalysis. The bulk of the p-cymene was probably formed by a menthadiene dehydrogenation reaction.

It must be mentioned that the rate of the conversions of the individual p-menthadienes into one another under the conditions of the experiment was higher than the rates of aromatization of a mixture and of their isomerization into compounds with different carbon skeletons. The amount of such isomers in experiments starting from the dienes amounted to 2-4%. The isomerization of (XI) and (XII) gave a complex mixture of products. In all cases the equilibrium mixtures contained the nine p-menthadienes (I-IX), the other theoretically possible p-menthadienes not being detected chromatographically. The materials balance of the experiments was drawn up with an accuracy of ±5%.

A number of papers [3, 7, 8] have described procedures for the GLC analysis of mixtures of p-menthadienes and compounds isomeric with them. However, they do not ensure a separation of the components that is adequate for quantitative calculations on a single liquid phase (LP). Since the isomerization of the dienes in a microreactor in the gas line of a chromatograph presupposes GLC analysis on a single column, we made a search for more selective LPs ensuring the required separation of the substances, using high-performance capillary columns. We tested LPs of different natures and polarities: triethyleneglycol butyrate, ethylene succinate, mannitol hexapropionitrile, squalene, tricresyl phosphate (TCP), oxydipropionitrile (ODPN), and others. The best results were obtained on the three last-mentioned LPs, but on TCP the peaks corresponding to (IV), (VI), and (X) were not separated completely, and on squalane those belonging to (I) and (X). The complete separation of the components of the isomeric mixtures was achieved on ODPN.

The quantitative interpretation of the chromatograms for this LP was made from the relative characteristics and the retention of a number of compounds [7] and by the addition of individual products to the isomeric mixture. The quantitative calculations were performed from the peak areas without the introduction of calibration factors.

The values of the equilibrium constants of the isomerization reactions of the p-menthadienes found from the figures of Table 1 for the gas phase and from the equilibrium concentrations in the liquid phase are given in Table 2. In spite of the fact that their values relate to different states of aggregation and temperatures, it can be stated that the equilibrium ratios of the dienes that we have obtained agree well with the results of previous work [4, 5]. The greatest discrepancies are found (Table 2) for reactions in which the equilibrium amount of one of the components is small and, consequently, difficult to determine with great accuracy.

A quantitative explanation of the distribution of amounts in an equilibrium mixture of p-menthadienes can be made on the basis of a comparison of the structures of the isomers and their influence on the enthalpy and entropy of the substances.

TABLE 3. Enthalpy and Entropy Factors of the Relative Stabilization of the p-Menthadienes

Compound	Enthalpy of stabilization, kJ/mole			Entropy factor		
	conjugation	change in the degree of substitution	total	total no. of "tops"	large "top"	"tops" with low barriers
I	−14,0	−13,8−13,8	−41,6	4	1	2(1)*
V	−14,0	−15,1−6,7	−35,8	3	—	2
IV	—	−13,8−13,8	−27,6	4	1	2(1)
III	−14,0	−13 8−6,7	−34 5	4	1	(1)
VI	−14,0	−13,8−7,9	−35,7	3	1	1
II	−14,0	−13,8−6,7	−34,5	4	1	1
VIII	—	−15,1−13,8	−28,6	3	—	3
VII	−14,0	−7 9−6,7	−28,6	3	1	—
IX	—	−13,8−7,9	−21,7	3	1	3(1)

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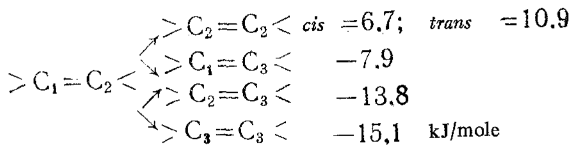
*(1) — large "top" with low value of the barrier.

Stabilization through the enthalpy factor is determined mainly by two circumstances:

1) the presence of conjugated double bonds stabilizes the molecule by approximately 14.0 kJ/mole [9]; and

2) an increase in the degree of substitution at the carbon atoms $>C_i{=}C_j<$ raises the stability of the isomers by the approximate values given in the scheme [10]:



Stabilization through the entropy factor in the menthadiene isomers should take place as the result of an increase in the number and dimensions of the rotating groups and a decrease in the size of the potential barriers for "spinning tops" adjacent to a double bond. Approximate estimates of the relative influence of the enthalpy and entropy factors on the stabilization of the isomers are given in Table 3.

It is obvious that (I) is the most stable isomer with respect to both factors. The high amount of (V) in the equilibrium mixture is also due to the unidirectional action of the energy and entropy factors, and that of (IV) to the higher entropy due to the increased — in comparison with the others (except (I)) — contributions of the internal rotation to the entropy. A satisfactory explanation of this type can also be given to characterize the ratios of the other isomers.

EXPERIMENTAL

GLC analysis was performed on a Chrom-42 chromatograph with a flame-ionization detector and 5000 × 0.02 cm steel capillary columns. The stationary phases were deposited from 20% solutions. The relative retention times of the components on the column containing ODPN at 70°C were: 0.59 (III); 0.86 (II); 0.98 (I); 1.00 (IX), 1.11 (VII); 1.31 (IV); 1.42 (VI); 1.54 (VIII); 1.65 (V); 1.92(X) . The retention time of (IX) was 115 min.

The initial preparations (I-XII), supplied by the Laboratory of Terpenoid Chemistry, Institute of Physical Organic Chemistry, Academy of Sciences of the Belorussian SSR, were characterized by their IR spectra [11] on a Spekord-75 IR instrument and by GLC, and contained up to 7% of isomeric products as impurities.

The microreactor, consisting of a steel tube with an internal diameter of 3 mm, was placed in the thermostat of an LKhM-8MD chromatograph and was connected by a heated nozzle to the evaporator and to the analytical chromatograph. The temperature regime was maintained with an accuracy of ±1.0°C and the rate of flow of argon was 20 ml/min. The catalyst was γ-alumina with a particle size of 0.3-0.4 mm.

SUMMARY

1. The isomerization equilibrium of nine p-menthadienes has been studied in the gas phase at 250°C and their equilibrium ratios have been determined.

2. A procedure has been developed for the quantitative GLC analysis of isomeric mixtures of p-menthadienes.

LITERATURE CITED

1. G. A. Rudakov, The Chemistry and Technology of Camphor [in Russian], Moscow—Leningrad (1961), p. 42.
2. H. Pines and H. E. Eschinazi, J. Am. Chem. Soc., 77, 6314 (1955); G. L. K. Hunter and W. B. Brogden, J. Org. Chem., 28, 1679 (1963).
3. I. I. Bardyshev, L. A. Popova, and E. F. Buinova, Izv. Akad. Nauk BSSR, Ser. Khim., No. 4, 112 (1976).
4. S. Bank, C. A. Rorve, A. Schriesheim, and L. A. Naslund, J. Org. Chem., 33, 221 (1968).
5. R. B. Bates, E. S. Caldwell, and H. P. Klein, J. Org. Chem., 34, 2615 (1969).
6. V. G. Berezkin, Analytical Reaction Gas Chromatography [in Russian], Moscow (1966), p. 18.
7. S. Geger, W. Ziger, S. Helm, and R. Mayer, Z. Chem., 5, 309 (1968).
8. I. I. Bardyshev and V. I. Kulikov, Zh. Anal. Khim., 23, 1081 (1968).
9. S. V. Petrova-Kuminskaya, O. M. Baranov, G. N. Roganov, and G. Ya. Kabo, Neftekhimiya, 23, 489 (1983).
10. I. A. Yursha and G. Ya. Kabo, Dokl. Akad. Nauk BSSR, 21, 1100 (1977).
11. B. M. Mitzner, E. T. Theimer, and S. K. Freeman, Appl. Spectrosc., 19, No. 6, 169 (1965).

ISOLATION OF NATIVE AGLYCONES FROM TRITERPENE GLYCOSIDES OF THE PACIFIC OCEAN HOLOTHURIAN *Cucumaria japonica*

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New native aglycones — 3β-hydroxyholosta-7,25-dien-16-one and holosta-7,25-dien-3β-ol — have been isolated from the glycosidic fraction of the holothurian *Cucumaria japonica*. It has been shown that holostane derivatives with a 16-keto group can be transformed on reduction with sodium tetrahydroborate into previously unknown compounds with an 18 → 16-lactone fragment.

As is well known, the aglycones of holothurian glycosides are unstable under the conditions of cleavage of glycosidic bonds. Therefore, proposals concerning the true structure of the triterpene moiety are made in many cases after the determination of the structure of the corresponding artefactual genins and the study of the ^{13}C NMR spectra of the initial glycosides. Thus, the structure of 3β-hydroxyholosta-7,25-dien-16-one (I) has been proposed for the main aglycone of the glycosides of the industrially caught Pacific Ocean holothurian *Cucumaria japonica* [1]. The native aglycone of glycosides of the Far Eastern trepang *Stichopus japonicus* is an isomeric compound — 3β-hydroxyholosta-9(11), 25-dien-16-one (II) [2].

Recently, to cleave the glycosides of *Bohadshia argus* we used the method of two-stage Smith degradation, as the result of which only native genins were obtained [3]. However, in the determination of the structure of holotoxin A_1 from *S. japonicus* [4] under the

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