PYRAN DERIVATIVES AS NEW PERFUMES

II.* STUDY OF THE PRODUCTS OF THE REACTION OF 1-NONENE WITH FORMALDEHYDE

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2-Nonyl acetate, 2-hexyltetrahydrofuran, 4-heptyl-1,3-dioxane, 3-hexyl-4-hydroxytetrahydropyran and its acetate, and decane-1,3-diol and its diacetate were isolated from the products of the reaction of 1-nonene with formaldehyde in acetic and sulfuric acids. The structures of the substances isolated were confirmed by the results of functional analysis and by IR and PMR spectroscopy. The stereoisomeric composition of 3-hexyl-4-hydroxytetrahydropyran and its acetate was established.

A method for the preparation of new perfumes – 3-alkyl-4-acetoxytetrahydropyrans, one of which, obtained from nonene, is being used in perfumery – via the Prins reaction has been described in previous publications [1, 2].

In this paper, we present data on the composition of a mixture obtained by the reaction of 1-nonene with formaldehyde according to the method in [2] and on the effect of the reaction conditions on the ratio of compounds obtained. Using vacuum rectification and chromatography with aluminum oxide-filled columns, we were able to isolate and identify the following principal substances: 2-nonyl acetate (I), 2-hexyltetrahydrofuran (II), 4-heptyl-1,3-dioxane (III), decane-1,3-diol (IV) and its diacetate (V), and 3-hexyl-4-hydroxytetrahydropyran (VI) and its acetate (VII) (Tables 1 and 2).

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*See [2] for communication I.

TABLE 1. Principal Substances Isolated from the Reaction of 1-Nonene with Formaldehyde

Compound	Amt. in the mixture,%	bp, °C (mm)	d_4^{20}	n_D^{20}	MR_D		Empirical formula	Found, %		Calc., %	
					found	calc.		C	H	C	H
I	1	78—80 (4)^4	—	1,4205	—	—	$C_{11}H_{22}O_2$	—	—	—	—
II	1—2	51—53 (5)^5	—	1,4356	—	—	$C_{10}H_{20}O$	—	—	—	—
III	11—12	68 (0,2)	0,9086	1,4420	54,20	54,08	$C_{11}H_{22}O_2$	71,1	12,1	70,9	11,9
IV^a	1—2	114—116 (0,25)^3				—	$C_{10}H_{22}O_2$	69,1	12,7	68,9	12,7
V^b	6—7	132 (0,8)	0,9921	1,4350	70,14	70,14	$C_{14}H_{26}O_4$	64,9	10,1	65,1	10,1
V^c	8—10	98—99 (0,2)	0,9564	1,4638	53,75	53,97	$C_{11}H_{22}O_2$	70,7	11,8	70,9	11,9
VII^d	44—45	84 (0,1)	0,9645	1,4495	63,55	63,33	$C_{13}H_{24}O_3$	68,6	10,6	68,4	10,6

[a] Solidification point 30.5-31° (benzene). [b] Ester number: found 437, calc. 434. [c] OH: found 8.82%, calc. 9.15%. [d] Ester No.: found 248.8, calc. 245.6.

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TABLE 2. Characteristic Frequencies of the IR Spectra of III and VI-VIII and PMR Spectral Data for VII

Compound	Characteristic frequencies in the IR spectrum, cm^{-1}*
III	724w, 815cw, 825m, 840m, 868w, 905m, 925m, 970s, 998s, 1040vs, , 1065s, 1092s, 1110s, 1132s, 1175s, 1198s, 1214s, 1250s, 1308w, 1354m, 1372s, 1408m, 1450m 1470s.
VI	725m, 785w, 810w, 858(shoulder)m, 887s, 939m, 998s; 10% solution in CCl_4 (*d* 0,1 mm): 1040s (δ OH_e), 1062s, 1090s (ν C—O—C ring), 1140(shoulder)s, 1152s, 1182w, 1228m, 1260m, 1300m, 1350m, 1380s (δ CH_3), 1446m, 1468s, 3440—3460s, 3624m, 3630w, (ν OH).
VII	725m, 785w, 820w, 895s, 915s, 962s, 1035ovs, 1065s, 1094 ovs (ν C—O—C-ring), 1132(sh)s, 1140s, 1165s; 2% solution in CCl_4 (*d* 0,165 mm): 244ovs (ν CH_3COO—), 1373m (δ CH_3), 1435w, 1470s, 1735ovs (ν CO).
VIII	724m, 766cw, 844m, 895m, 978s, 1040m, 1105s (ν C—O—C ring), 1122m, 1158s, 1218ovs, 1248s, 1282s, 1315m, 1375s (δ CH_3), 1418s, 1468s, 1715oч.vs, (ν CO).
VII	PMR spectrum δ,ppm.; H attached to $C_{(4)}$: H_e 5,03 (quartet), H_a 4,57 (sextet); JH_4H_{3a} 3,8 ; 9Hz. JH_4H_{5a} 3,8 ; 9 Hz JH_4H_{5e} 3,8Hz; δ OAc_e 1,98 (singlet), δ OAc_a 2,00 (singlet).

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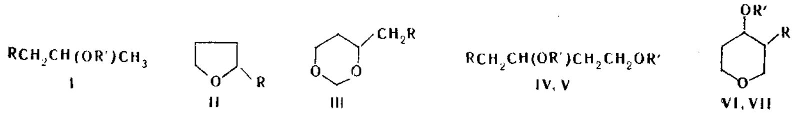
*The following symbols were used: w corresponds to 20-40% absorption, m corresponds to 40-60% absorption, s corresponds to 60-90% absorption, and vs corresponds to more than 90% absorption.

TABLE 3. Effect of the Reaction Conditions on the Ratio of the Principal Substances (III and V-VII)

Catalyst (% of the weight of the reaction mass)	Reaction time, h	Percentage in the mixture of reaction prod., % (deter. by gas-liquid chromatography			
		III	V	VI	VII
H_2SO_4 (5)	4	21	2	11,5	37
H_2SO_4 (10)	2	18	5	9,5	41,5
H_2SO_4 (10)	4	9	7	9	49
$BF_3 \cdot AcOH$ (5)	4	10	4	10	28
$BF_3 \cdot AcOH$ (10)	4	13	5	11	37
$HClO_4$ (5)	4	20	2	13	27
$HClO_4$ (10)	4	15,5	5,5	11,5	25,5
H_3PO_4 (10)	4	95% of the nonene was recovered			



R = C_6H_{13}; IV, VI R' = H; I, V, VII R' = Ac

2-Nonyl acetate (I) is identical to the acetate obtained by the addition of acetic acid to 1-nonene, while 2-hexyltetrahydrofuran (II) is identical to the product of the cyclization of decane-1,4-diol. The structure of 4-heptyl-1,3-dioxane (III) was confirmed by converting it to decane-1,3-diol (IV), which is identical to the substance isolated from the reaction products and the substance synthesized by a different route [3]. The IR spectrum of III confirms the presence of a dioxane ring. Decane-1,3-diol diacetate (V) proved to be identical to the diacetate obtained from a known sample of IV.

The structure of 3-hexyl-4-acetoxytetrahydropyran (VII) was proved by its saponification to 3-hexyl-4-hydroxytetrahydropyran (VI) and by oxidation of the latter to 3-hexyltetrahydro-γ-pyrone (VIII). The structures of all three substances were also confirmed by the results of IR spectroscopy. All of the physicochemical indexes of pyranol VI, isolated from the products of the Prins reaction, are identical to those of the pyranol obtained by a saponification of VII, and its acetate is identical to VII.

It is known that 3-alkyl-4-hydroxytetrahydropyrans and their acetates, which are formed in the Prins reaction, can exist as two stereoisomers — the trans isomer with diequatorial substituents and the cis isomer with equatorial alkyl groups and axial OH or OAc groups [6, 7]. The chromatograms of VI and VII are unsymmetrical peaks; the IR spectrum also indicates the predominance of the trans isomer in VI. According to the PMR spectra, VII contains 66% trans and 34% cis isomer; this is in agreement with the literature data for other 3-alkyl-4-pyranols [6, 7]. Unfortunately, isomers of VI and VII cannot be separated either by column chromatography with aluminum oxide, silica gel, or silic acid or, despite the existing analogies [6, 7], by means of gas-liquid chromatography on the most diverse phases in capillary and standard columns.

In order to increase the yield of VII, which is an aromatic principle with a strong jasmine odor, we studied the effect on the ratio of the reaction products of the reaction duration and amount of sulfuric acid and other Prins-reaction catalysts [8-10] – phosphoric and perchloric acids and a complex of boron trifluoride with acetic acid. The results demonstrate (Table 3) that the indicated catalysts do not have advantages over sulfuric acid. The greatest yield of VII was achieved under the conditions that we previously selected in [2].

EXPERIMENTAL

The IR spectra of thin films (d 0.02 mm) of samples of CCl_4 solutions were recorded with a UR-10 spectrograph in a NaCl cuvette. The PMR spectra of 10% solutions of the samples in CCl_4 were recorded with a Varian HA-100D spectrometer with an operating frequency of 100 MHz; the shifts were measured relative to tetramethylsilane as the internal standard.* Gas-liquid chromatographic analysis of the product of the reaction of the isolated and synthesized compounds was performed with a Willy Giede F-12 chromatograph (German Democratic Republic) in a stream of helium with thermal conductivity detection. The stationary phase was octahydroxypropyl sucrose (20%) on Chromosorb W with a 3-m long column with a diameter of 0.4 cm; the temperature was 120-165°, and the helium flow rate was 120-130 ml/min. The following columns were tested in attempts to separate the stereoisomers of the tetrahydropyran derivatives (VI and VII): a 100-m long capillary column with a diameter of 0.01 mm, Apiezon L; a 100-m long capillary column with a diameter of 0.02 mm, SE-30 silicone elastomer; a 2-m long micropacked column with an inner diameter of 1.5 mm, Versamid-930 (2%) on Chromosorb W (80-100 mesh, treated with CDMS (chlorodimethylsilane); a 2-m long packed glass column with a diameter of 3 mm, Lac-2R-446 (15%) on Chromosorb W (80-100 mesh) (Perkin-Elmer F-11 chromatograph); a 0.68-m long packed column with a diameter of 6 mm, 1.5% E-301 silicone elastomer on Chromosrob W (60-80 mesh, treated with CDMS) (Khrom-31 chromatograph).

Reaction of 1-Nonene with Formaldehyde and Isolation of the Major Substances. 1-Nonene (99% pure according to gas-liquid chromatography) was obtained by the pyrolysis of nonyl acetate and had bp 146-147°, n_D^{20} 1.4157, and bromine number 126.8 [12]. The Prins reaction and vacuum distillation of the reaction products into four major fractions were carried out as described in [2]. Chromatography on activity I aluminum oxide with elution by petroleum ether yielded I and II from the first fraction and III from the second fraction. Compound VII was isolated from the third fraction, which contained more than 90% VII, with a column filled with activity V aluminum oxide with elution by petroleum ether with gradual addition (up to 20%) of ether. Compounds IV-VI were similarly isolated from the fourth fraction. The characteristics of the chromatographically pure isolated substances are presented in Tables 1 and 2.

Methanolysis of 4-Heptyl-1,3-dioxane (III). A flask with a fractionating column was charged with 8 g of III, 200 ml of dry methanol, and 0.5 g of concentrated sulfuric acid. In the course of 10-12 h, the formaldehyde was distilled off along with methanol into a receiver containing an aqueous solution of 2,4-dinitrophenylhydrazine hydrochloride until the precipitation of the hydrazone ceased. A total of 1.08 g (72%) of formaldehyde hydrazone with mp 131-132° [4] was obtained. The methanol was removed from the reaction mass by distillation, and, after neutralization and the usual workup, vacuum distillation of 6.8 g of residue yielded 4.1 g (55%) of IV. This product did not depress the melting point of an authentic sample of decane-1,3-diol.

3-Hexyl-4-hydroxytetrahydropyran (VI). Saponification of 12 g of VII with 12% potassium hydroxide in 90% aqueous alcohol yielded 8.1 g (78.5%) of 95% pure VI. Purification of this sample with a column filled with activity V aluminum oxide with elution with petroleum ether–ether (4:1) yielded 4.6 g of VI.

3-Hexyltetrahydro-γ-pyrone (VIII). A solution of 4 g of VI in 25 ml of ether was heated for 30 min with a mixture of 2.7 g of sodium dichromate, 8 g of concentrated sulfuric acid, and 20 ml of water [13]. After the usual workup, vacuum distillation yielded 1.7 g (43%) of 98% pure VIII with bp 80-81° (0.3 mm), d_4^{20} 0.9507, and n_D^{20} 1.4551. Found: C 71.7; H 10.9; CO (oxime formation) 15.3%; MR_D 52.60. $C_{11}H_{20}O_2$. Calculated: C 71.7; H 10.9; CO 15.2%; MR_D 52.45. The 2,4-dinitrophenylhydrazone of VIII had mp 113.5-114° (alcohol). Found: N 15.5%. $C_{17}H_{24}N_4O_5$. Calculated: N 15.4%.

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*The PMR spectra were recorded and interpreted in the physicochemical laboratory of the V. A. Korenevskii Institute, while the gas-liquid chromatographic analysis was performed by R. I. Sharapova and A. S. Leshchinder.

Decane-1,3-diol Diacetate (V). This compound was obtained in 82% yield from the diol of known structure by acetylation with acetic anhydride in the presence of perchloric acid [2].

Decane-1,4-diol. This compound was obtained from allyl alcohol and 1-heptanol by the method in [5] and had bp 120° (0.15 mm) and n_D^{20} 1.4560 [5]; according to gas-liquid chromatography, the product contains 1-3% 1-heptanol.

2-Hexyltetrahydrofuran (II). This compound was obtained in 80% yield by the cyclization of decane-1,4-diol in the presence of 0.1% p-toluenesulfonic acid.

2-Nonyl Acetate (I). A mixture of 25 g of 1-nonene, 75 g of acetic acid, and 6.5 g of concentrated sulfuric acid was refluxed for 2 h. After the usual workup, vacuum distillation yielded 17 g (46.2%) of I containing 6-8% of an impurity (apparently acetates of isomeric nonanols).

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