CONDENSATION OF 2-(1-ETHOXYVINYL)OXIRANES WITH SODIOMALONIC ESTER AND DECARBOXYLATION OF THE REACTION PRODUCTS OBTAINED

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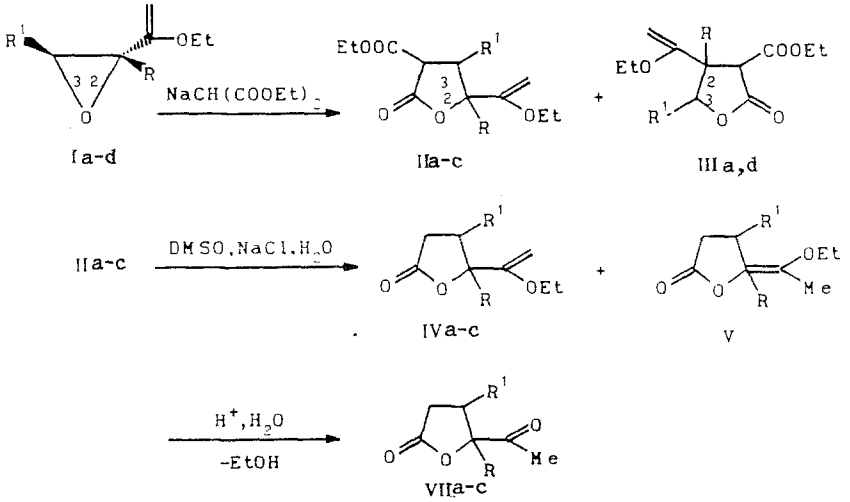
γ-(1-Ethoxyvinyl)- and β-(1-ethoxyvinyl)-α-ethoxycarbonyl-γ-butyrolactones were obtained by the reaction of 2-(1-ethoxyvinyl)oxiranes with sodiomalonic ester. Decarboxylation of the γ-(1-ethoxyvinyl)-α-ethoxycarbonyl-γ-butyrolactones in DMSO leads to γ-(1-ethoxyvinyl)-γ-butyrolactones, the hydrolysis of which gives γ-acetyl-γ-butyrolactones. Ethyl trans-3-acetyl-3-pentenoate was obtained by decarboxylation of γ-methyl-β-(1-ethoxyvinyl)-α-ethoxycarbonyl-γ-butyrolactone in DMSO.

The γ-butyrolactone fragment is encountered in a number of natural compounds and is often responsible for their biological activity [1]. A convenient method for the synthesis of γ-lactones is the condensation of oxiranes with sodium derivatives of malonic ester and other CH acids similar to it [2].

In the present research we carried out more detailed studies of the condensation of 2-(1-ethoxyvinyl)oxiranes with sodiomalonic ester. In [3] it was pointed out that the epoxide ring in 2-(1-ethoxyvinyl)oxirane (Ia) opens only at the $C_{(3)}$ ring to give α-ethoxycarbonyl-γ-(1-ethoxyvinyl)-γ-butyrolactone (IIa). However, additional studies showed that opening of the epoxy ring in this compound occurs not only at the $C_{(3)}$ atom but also at the $C_{(2)}$ atom to give a mixture of ester IIa and its regioisomer IIIa in a ratio of 3:1.



I-IV, VII*: a) R = R^1 = H; b) R - α-Me, R^1 = β-H; c) R = α-Me, R^1 = β-Me; d) R = α-H, R^1 = β-Me.

*The spatial orientations of the substituents are indicated for II-IV and VII.

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TABLE 1. Characteristics of the Synthesized Compounds

Compound	Empirical formula	Tbp, °C (mm of Hg)	n_D^{20}	Yield, %
Ic	$C_6H_{11}O_2$	46...48 (12)	1,4325	86
IIc	$C_{13}H_{20}O_5$	120...124 (1)	1,4556	61
IIIa	$C_{11}H_{16}O_5$	—	1,4592	14
IVa	$C_8H_{12}O_3$	—	1,4615	68
IVb	$C_9H_{14}O_3$	72...75 (1)	1,4547	92
IVc	$C_{10}H_{16}O_3$	75...76 (1)	1,4547	88
V	$C_8H_{12}O_3$	—	1,4582	11
VI	$C_9H_{14}O_3$	80...82 (1)	1,4644	62
VIIa	$C_6H_8O_3$	134...137 (12)	1,4624	63
VIIb	$C_7H_{10}O_3$	118...120 (13)	1,4557	73
VIIc*	$C_8H_{12}O_3$	85...87 (1)	—	70

*Compound VIIc began to crystallize on standing to give a solid with mp 51-52°C.

TABLE 2. Data from the IR and PMR Spectra of the Synthesized Compounds

Compound	IR spectrum, cm^{-1}	PMR spectrum, δ, ppm SSCC (J), Hz
Ic	1656, 1617	1,27 (3H, d J = 5,5); 1,31 (3H, t J = 7,0); 1,31 (3H, s); 2,78 (1H, q J = 5,5); 3,67 (2H, q, J = 7,0); 3,73 (1H, d, J = 2,6); 4,08 (1H, d J = 2,6)
IIc	1779, 1720, 1661, 1620	1,02 (3H, d J = 6,8); 1,29 (3H, t J = 7,0); 1,30 (3H, t J = 7,0); 1,58 (3H, s); 2,75 (1H, m); 3,51 (1H, d J = 12,0); 3,75 (2H, q J = = 7,0); 4,13 (1H, d J = 3,2); 4,21 (1H, d J = 3,2); 4,23 (2H, q J = = 7,0)
IIIa	1784, 1727, 1668, 1621	1,26 (3H, t J = 7,0); 1,29 (3H, t, J = 7,0); 3,67 (1H, d J = 5,6); 3,67 (1H, m); 3,73 (2H, q J = 7,0); 3,98 (1H, d, J = 2,7); 4,03 (1H, d, J = 2,7); 4,18 (1H, d.d, J = 2,7, J = 5,7); 4,23 (2H, q J = = 7,0); 4,44 (1H, d.d, J = 2,7, J = 5,7)
IVa	1781, 1664, 1627	1,30 (3H, t, J = 7,0); 1,90...2,54 (4H, m); 3,74 (2H, q, J = 7,0); 2,93 (1H, d, J = 2,5); 4,13 (1H, d, J = 2,5); 4,67 (1H, m)
IVb	1782, 1665, 1622	1,30 (3H, t J = 7,0); 1,48 (3H, s); 1,90...2,50 (4H, m); 3,73 (2H, J = 7,0); 3,90 (1H, d, J = 2,8); 4,23 (1H, d, J = 2,8)
IVc	1783, 1667, 1623	0,83 (3H, t, J = 6,4); 1,15 (3H, s) J = 7,0); 1,32 (3H, s); 1,77...2,30 (3H, m ; 3,53 (2H, q, J = 7,0); 3,83 (1H, d, J = 2,8); 4,03 (1H, d, J = 2,8)
V	1785, 1664	1,19 (3H, t, J = 7,0); 1,82 (3H, s); 2,10...2,95 (4H, m); 3,63 (2H, q J = 7,0)
VI	1728, 1667	1,23 (3H, t, J = 7,0); 1,88 (3H, d, J = 6,9); 2,32 (3H, s); 3,33 (2H, s); 4,10 (2H, q J = 7,0); 6,91 (1H, q J = 6,9); 2,00...2,73 (4H, m); 2,27 (3H, s); 4,80 (1H, m)
VIIa	1780, 1723	2,00...2,73 (4H, m); 2,27 (3H, s); 4,80 (1H, m)
VIIb	1780, 1725	1,42 (3H, s); 1,82...2,55 (4H, m); 2,15 (3H, s)
VIIc	1782, 1726	0,97 (3H, d, J = 7,2); 1,47 (3H, d); 2,20 (3H, s); 2,21 (1H, d.d J = = 6,5, J = 17,5); 2,47 (1H, m); 2,77 (1H, d.d, J = 8,4, J = 17,5)

It was also established that the condensation of trans-2,3-dimethyl-2-(1-ethoxyvinyl)oxirane (Ic) with sodiomalonic ester proceeds with opening of the epoxy ring at the $C_{(3)}$ atom to give lactone IIc, while the product of the reaction of trans-3-methyl-2-(1-ethoxyvinyl)oxirane (Id) is, in conformity with the data in [4], lactone IIId. Both lactones are diastereomerically homogeneous compounds.

The spatial orientation of the substituents in lactones IIc and IIId was established on the basis of PMR spectral data using the Overhauser effect. Irradiation by the resonance frequency of the protons of the γ-methyl group of lactone IIc increases the intensity of the signal of the β proton. The effect of the resonance frequency on the protons of the β-methyl group increases the intensity of the signal of the β proton. These data make it possible to assume that the γ- and β-methyl groups,

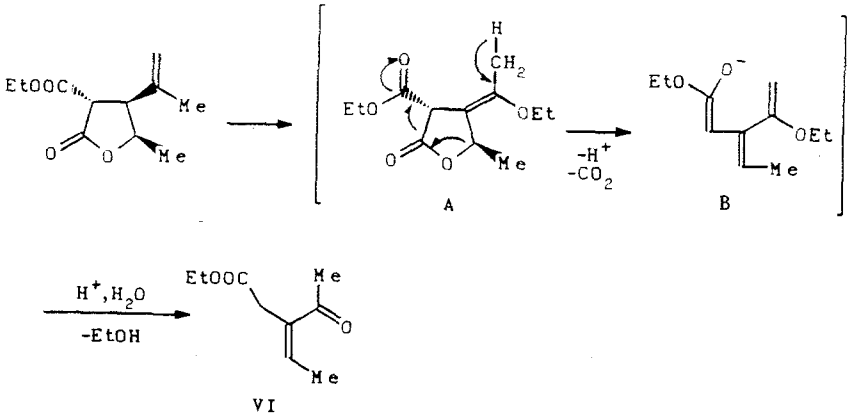
as well as the β-methyl and α-ethoxycarbonyl groups, are trans-oriented relative to one another. In the case of irradiation by the resonance frequency of the γ-proton of lactone IIId one observes an increase in the signal of the β proton, while irradiation of the β proton leads to an increase in the intensity of only the γ proton, which is possible if the β and γ substituents are cis-oriented relative to one another, and the β and α substituents are trans-oriented relative to one another.

Lactone IIIa is a diastereomerically homogeneous compound; however, the spatial orientation of the substituents could not be established.

The decarboxylation of IIa-c and IIId in moist DMSO in the presence of sodium chloride at 160°C was studied. It was found that under these conditions lactone IIa forms a mixture of isomeric lactones IVa and V in a ratio of 6:1. Compounds IVa and V were isolated by means of column chromatography. Treatment of lactone IVa with trifluoroacetic acid in CCl_4 leads to a mixture of it with V in the same ratio. Compounds IIb, c are decarboxylated to give γ-(1-ethoxy)-γ-butyrolactones IVb, c in up to 92% yields. The decarboxylation of ester IIId unexpectedly leads to ethyl trans-3-acetyl-3-pentenoate (VI).

Irradiation by the resonance frequency of the protons of the acetyl group of VI increases the intensity of the signal of the vinyl proton, while in the case of irradiation by the resonance frequency of the protons of the methyl group attached to the double bond one observes an increase in the intensity of the signal of the protons of the methylene group. This is possible if VI has an E configuration.

It might be assumed that the decarboxylation of lactone IId is realized through intermediate form A, from which triene B is formed, while ester VI is obtained by hydrolysis of the latter.



The hydrolysis of γ-(1-ethoxyvinyl)-γ-butyrolactones IVb, c, as well as a mixture of IVa and V, in the presence of perchloric acid leads to γ-acetyl-γ-butyrolactones VIIa-c. Compound VIIa (solerone) is a natural substance that is responsible for the taste and odor of various wines [5].

EXPERIMENTAL

The IR spectra of solutions of the substances in CCl_4 were recorded with a Specord IR-75 spectrometer. The PMR spectra were obtained with Tesla BS-467 (for solutions in CCl_4) and Bruker WM-360 (for solutions in $CDCl_3$) spectrometers with tetramethylsilane (TMS) as the internal standard.

The purity and individuality of the compounds were monitored by TLC [on Silufol UV-254 plates in an ether—hexane (1:1) system with development by iodine vapors or saturated potassium permanganate solution].

The characteristics of the compounds are presented in Table 1, while data from their IR and PMR spectra are presented in Table 2. The results of elementary analysis of IIc, IIIa, IVa-c, V, VI, and VIIa-c for C and H were in agreement with the calculated values.

The starting 2-(1-ethoxyvinyl)oxiranes Ia-d were synthesized via a known method [6]; their constants were in agreement with those presented in the literature.

γ-(1-Ethoxyvinyl)- and β-(1-Ethoxyvinyl)-α-(ethoxycarbonyl)-γ-butyrolactones (IIa-c and IIIa, d). A 0.22-mole sample of sodium metal was dissolved in 70 ml of absolute ethanol, and 0.30 mole of malonic ester and 0.20 mole of one of the ethoxyvinyloxiranes Ia-d were added to the resulting solution of sodium ethoxide. The reaction mixture was heated until the starting oxirane vanished (2-3 h in the case of Ia, b or 20-25 h in the case of Ic, d), after which it was cooled to room temperature, diluted with 200 ml of ether, neutralized with glacial acetic acid (0.22 mole), diluted with 200 ml of ice water, and extracted with ether. The combined ether extracts were washed with water, dried with Na_2SO_4, and concentrated at

reduced pressure, and the residue was fractionally distilled in vacuo. This procedure gave a mixture of γ-butyrolactones IIa and IIIa from oxirane Ia, the corresponding lactones IIb, c from Ib, c, and product IIId from Id. The mixture of IIa and IIIa was separated by means of column chromatography on silica gel [elution with ether—hexane (1:1)]. The physicochemical characteristics of lactones IIa, b and IIId were in agreement with those presented in [3].

γ-(1-Ethoxyvinyl)-γ-butyrolactones (IVa-c), γ-(1-Ethoxyethylidene)-γ-butyrolactone (V), and Ethyl trans-3-Acetyl-3-pentenoate (VI). A mixture of 0.1 mole of one of the lactones IIa-c or IIId, b, 3.6 g (0.2 mole) of water, and 5.83 g (0.1 mole) of sodium chloride in 100 ml of DMSO was stirred in a flask equipped with a reflux condenser at 160°C in an argon atmosphere for 2-3 h, after which the reaction mixture was diluted with 1 liter of ether, and the resulting mixture was washed with water (2 × 100 ml and 3 × 30 ml) and saturated sodium chloride solution (2 × 100 ml). The combined aqueous layers were extracted with ether, the combined organic layers were dried with Na_2SO_4, the ether was removed at reduced pressure, and the residue was fractionally distilled in vacuo. Lactone IIa gave a mixture of IVa and V [bp 79-82°C (1 mm)], IIb, c gave the corresponding products IVb, c, and IIId gave ester VI. The mixture of lactones IVa and V was separated by column chromatography on silica gel [elution with ether—hexane (1:1.5)].

γ-Acetyl-γ-butyrolactones (VIIa-c). A mixture of 5 ml of water, 5 ml of dioxane, several drops of 60% perchloric acid, and 0.01 mole of one of the butyrolactones (IVb, c or a mixture of IVa and V) was stirred vigorously at room temperature for 5-7 h until the starting compound vanished (monitoring by TLC), after which the reaction mixture was neutralized with triethylamine and extracted repeatedly with ether. The combined ether extracts were washed with a small amount of water and dried with anhydrous Na_2SO_4. The ether was then removed at reduced pressure, and the residue was fractionally distilled in vacuo. This procedure gave VIIa from the mixture of IVa and V and VIIb, c, respectively, from lactones IVb, c.

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