SYNTHESIS OF 2-OXO-3H-FURO[3,2-c]PYRYLIUM SALTS AND 4-PYRONE-3-ACETIC ACID BY ACYLATION OF β-AROYLPROPIONIC ACIDS

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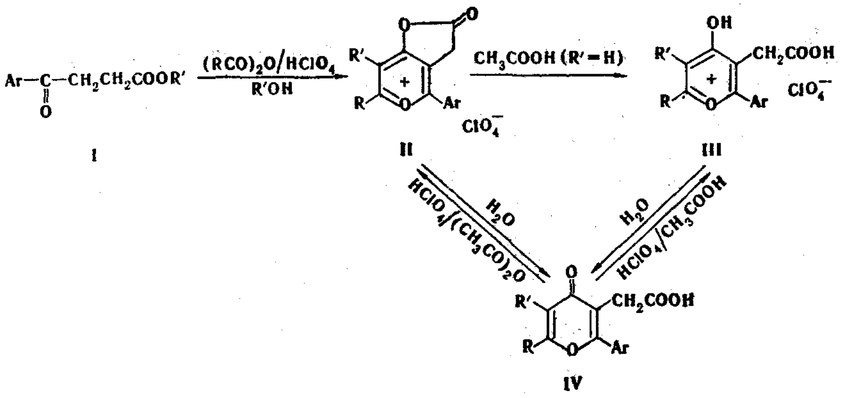
UDC 547.724'812.5.07:542.951.1

Earlier the abnormal diacylation of phenylacetaldehyde and its enol acetate, accompanied by heterocyclization to γ-hydroxypyrylium salts, was observed [1]. In the opinion of the authors this reaction involves the states of initial acylation of the α-carbon atom of phenylacetaldehyde and subsequent acylation of the intermediately formed ketone at the methyl and methylene groups (acylation of the "head-to-tail" type).

In the present work we discovered a similar transformation during the acylation of β-benzoylpropionic acid, its ethyl ester, and other β-aroylpropionic acids by the anhydrides of aliphatic acids in the presence of catalytic and equimolar amounts of perchloric acid. Here a series of unknown lactone-pyrylium salts (II) (2-oxo-3H-furo[3,2-c]pyrylium perchlorates) were obtained.



In the PMR spectrum of the perchlorate (IIb), compared with the spectrum of the perchlorate (IIa), the absence of the signal for the β-proton of the pyrylium ring in addition to the presence of signals for the methyl and ethyl groups confirms the structure proposed for the pyrylium salts (IIa, b). This in turn shows that two molecules of the acid anhydride are involved in the creation of the pyrylium ion.

In the IR spectra of the uncrystallized salts (II), apart from bands characteristic of substituted pyrylium salts [2], there is a high-intensity absorption band at 1870 cm^{-1}, which we assigned to the stretching vibrations of the γ-lactone [3], condensed with the pyrylium ion. The intensity of this band in the spectra of certain pyrylium salts (II) (R' = H) decreases considerably after a single crystallization from glacial acetic acid. At the same time, a band in the region of 1720 cm^{-1}, the intensity of which increases after repeated crystallization, appears in the IR spectra of these compounds, whereas the bands at 1870 and 1584-1568 cm^{-1}, which are evidently also due to the presence of the lactone, disappear completely.

This fact shows that the γ-lactone ring is unstable in the absence of a substituent at position 5 of the salts (II) and that it undergoes hydrolytic cleavage to form previously

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TABLE 1. 2-Oxo-3H-furo[3,2-c]pyrylium (II) and 4-Hydroxy-3-carboxymethylpyrylium (III) Perchlorates

Compound	Ar	R	R′	mp, °C[a]	IR spectra, cm^{-1}, characteristic frequencies	Found, %			Molecular formula	Calculated, %			Yield, %
						C	H	Cl		C	H	Cl	
IIb[b]	C_6H_5	C_2H_5	CH_3	212	1870 1642 1606 1583 1537 1500	54,3	4,3	10,3	$C_{16}H_{15}ClO_7$	54,2	4,2	10,0	38
IIc		C_3H_7	C_2H_5	184—185	1870 1638 1585 1525 1500 1594	56,0	5,1	8,9	$C_{18}H_{18}ClO_7$	56,5	4,9	9,3	26
IIIc		C_3H_7	C_2H_5	145—146	1723 1638 1530 1500	54,3	5,2	9.0	$C_{18}H_{20}ClO_8$	54,0	5,1	8,9	39
IId		C_6H_9	C_3H_7	158—159	1870 1638 1590 1530 1500	59,4	5,9	8,8	$C_{20}H_{25}ClO_7$	59,5	6,1	8,58	57
IIIk	4-$CH_3C_6H_4$	CH_3	H	196—197	1723 1644 1559 1504	50,2	4,4	9,5	$C_{15}H_{15}ClO_8$	50,2	4,2	9,9	48
IIIf	4-$C_2H_5C_6H_4$			188—189	1726 1640 1617 1548 1510	51,5	4,7	9,3	$C_{16}H_{17}ClO_8$	51,6	4,6	9,5	36
II, IIIg[c]	4-(*i*-C_3H_7)C_6H_4			228—230	1878 1740 1642 1612 1574 1537 1512								32
IIIh	2,4-$(CH_3)_2C_6H_3$			170—171		51,8	4,6	10,0	$C_{16}H_{17}ClO_8$	51,7	4,6	9,5	48
IIIi	3,4-$(CH_3)_2C_6H_3$			186—187[d]	1718 1640 1614 1552 1500	51,8	4,5	9,3	$C_{16}H_{17}ClO_8$	51,6	4,6	9,5	36
IIIj	4-ClC_6H_4			193	1712 1640 1598 1550	44,2	3,6	17,9	$C_{14}H_{12}Cl_2O_8$	44,4	3,2	18,4	49
IIIk	4-BrC_6H_4			226—228	1710 1640 1593 1550	39,2	3,0	26,9	$C_{14}H_{12}ClBrO_8$	39,6	2,8	27,1	53
III*l*	3,4-$Cl_2C_6H_3$			204—205	1720 1640 1600 1560 1500	40,9	3,0	25,6	$C_{14}H_{11}Cl_3O_8$	40,6	2,6	25,6	64
IIIm	C_6H_5	C_7H_{15}	C_6H_{13}	decomp. 70°	1877 1638 1584 1527 1502	62,5	9,5	7,6	$C_{26}H_{37}ClO_7$	62,8	9,6	7,1	36

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[a] Crystallization from glacial acetic acid. [b] PMR spectrum: 1.15 (3H, t, 6-CH_2—CH_3), 2.02 (3H, s, 5-CH_3), 2.92 (2H, q, 6-CH_2—CH_3), 4.00 (2H, s, —CH_2—), 7.25-7.70 ppm (5H, m, C_6H_5). [c] Mixture of II and IIIg, 1:2. [d] Reprecipitated from acetone with ether.

unknown 4-hydroxy-3-carboxymethylpyrylium salts (III) (Table 1). The hydroxypyrylium salts (III) containing one or two molecules of water are formed during recrystallization of the perchlorate (IIa) and its analogs (R^1 = H). This is demonstrated by the data from elemental analysis and also by the broad absorption bands in the region of 3500 cm^{-1} in the IR spectra of the compounds and by the six-proton broadened signal in the PMR spectrum of the perchlorate (IIIa), which disappear when the salts are dried under vacuum.

During hydrolysis of the synthesized pyrylium salts (II, III) the previously undescribed 4-pyrone-3-acetic acids (IV) were obtained with almost quantitative yields (Table 2). Thus, the acid diacylation of aroylpropionic acids significantly extends the range of previously known cases of the synthesis of γ-pyrones, based on the acylation of methyl (or methylene) groups in ketones by aliphatic acids, in polyphosphoric acid [4-6] or by their anhydrides in the presence of boron trifluoride. It may provide a convenient method for the production of new 3-carboxymethylpyrylium salts and γ-pyrones, which are the analogs of the arylacetic acids widely used in organic synthesis.

As shown for the case of compounds (IVa, c), the pyrones give the initial perchlorates (IIa, c) under the influence of equimolar amounts of perchloric acid in the presence of acetic anhydride. The protonation of these pyrones in glacial acetic acid leads to the production of the dihydrate of the salt (IIIa) and the unknown perchlorate (IIIc) and can be used for the production of other (5-substituted) carboxymethylpyrylium salts (III).

EXPERIMENTAL

The PMR spectra of compounds (IIa) and (IIIa) in trifluoroacetic acid were recorded on a BS-467 instrument (60 MHz). The spectra of the dihydrate of compound (IIIa) in acetonitrile and of (IVa) in methylene chloride and nitromethane were recorded on an RYa-2305 instrument at 60 MHz and at 20°C with HMDS as internal standard. The IR spectra were recorded on a UR-20 spectrophotometer in Vaseline oil.

2-Phenyl-6-methyl-2-oxo-3H-furo[3,2-c]pyrylium Perchlorate (IIa). To a suspension of 1.78 g (0.01 mole) of β-benzoylpropionic acid in 7 ml of acetic anhydride we slowly added 1 ml (0.01 mole) of 70% perchloric acid. The mixture was heated on a water bath for 15-20 min. After cooling, we slowly added 3-4 ml of ether to the reaction mixture and filtered off 0.69 g (39%) of colorless crystals; mp 216°C. IR spectrum: 1862, 1636, 1572, 1524, 1100 cm^{-1}. PMR spectrum: 2.60 (3H, s, 6-CH_3), 4.00 (2H, s, —CH_2—), 7.12 (1H, s, $=\overset{|}{C}H$—), 7.25-7.70 ppm (5H, m, C_6H_5). Found %: C 51.6; H 3.5; Cl 10.4. $C_{14}H_{11}ClO_7$. Calculated %: C 51.4; H 3.4; Cl 10.8.

During twofold recrystallization of the perchlorate (IIa) from glacial acetic acid we obtained the perchlorate (IIIa)·$2H_2O$; mp 219-222°C. IR spectrum: 3520, 1718, 1630, 1548, 1100 cm^{-1}. PMR spectrum: 2.56 (3H, s, 6-CH_3), 3.53 (2H, s, —CH_2—), 5.38 (6H, s, $=\overset{|}{C}$—OH, $\overset{|}{C}OOH$,

TABLE 2. 4-Pyrone-3-acetic Acids

Compound	mp, °C[a]	IR spectra, cm^{-1}				Found, %		Molecular formula	Calculated, %	
		COOH	C=O	C=C	arom.	C	H		C	H
IVb	190—191	1750	1660	1594	1500	70,8	6,2	$C_{16}H_{16}O_4$	70,6	5,9
IVc	105—106	1750	1650	1590		72,4	7,3	$C_{18}H_{20}O_4$	72,0	6,7
IVd	114—115	1711	1660	1590		73,5	7,2	$C_{20}H_{24}O_4$	73,2	7,3
IVe	193—194					69,5	5,5	$C_{15}H_{14}O_4$	69,7	5,4
IVf	163—164	1728	1650	1619	1585	70,4	5,9	$C_{16}H_{16}O_4$	70,5	5,9
IVg	103—104	1726	1651	1607	1586	68,1	4,9	$C_{17}H_{18}O_4$	68,2	4,9
IVh	106—108	1731	1660	1608	1586	70,7	5,9	$C_{16}H_{16}O_4$	70,5	5,9
IVi	191—192	1724	1660	1620	1603 1570	70,8	5,9	$C_{16}H_{16}O_4$	70,6	5,9
IVj[b]	217	1711	1638	1598	1550	60,4	4,3	$C_{14}H_{11}ClO_4$	60,4	3,9
IVk[b]	210—211	1721	1641	1586		52,2	3,9	$C_{14}H_{11}BrO_4$	52,0	3,4
IVl[b]	177—178	1731	1653	1590		53,9	3,6	$C_{14}H_{10}Cl_2O_4$	53,7	3,2
IVn[c]	75—76	1750	1649	1580		59,0	7,6	$C_{22}H_{28}O_4$	58,9	7,9

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a) From aqueous alcohol, b) For (IVj-l), respectively, found %: Hal 13.1, 24.2, and 22.3. Calculated %: Hal 12.7, 24.8, and 22.7. c) Ar = C_6H_5, R = C_4H_9, R^1 = C_5H_{11}.

$2H_2O$), 7.00 (1H, s, $=CH-$), 7.56 (5H, s, C_6H_5). Found %: C 44.5; H 4.5; Cl 9.3. $C_{14}H_{13}ClO_8 \cdot 2H_2O$. Calculated %: C 44.2; H 4.5; Cl 9.3. The perchlorate (IIIa)·$2H_2O$ is dehydrated by drying in a vacuum drying pistol over phosphorus pentoxide. Found %: C 48.5; H 3.8; Cl 10.3. $C_{14}H_{13}ClO_3$. Calculated %: C 48.7; H 3.8; Cl 10.3.

The pyrylium salts (IIb-*l*) were synthesized similarly from the corresponding β-aroylpropionic acids (I) [7, 8] and propionic, butyric, and valeric anhydrides. During recrystallization from glacial acetic acid the perchlorates (IIe-*l*) (R^1 = H) were converted with the exception of the perchlorate (IIg) into the pyrylium salts (III) (Table 1).

The perchlorate (IIa) was obtained similarly by the general method from ethyl β-benzoylpropionate (bp 128°C at 2 mm Hg) [9], acetic anhydride, and perchloric acid with a 27% yield.

2-Phenyl-3-carboxymethyl-6-methyl-4-pyrone (IVa). Compound (IVa) was obtained with an 85-90% yield by heating the perchlorates (IIa, IIIa, IIIa·$2H_2O$) to boiling in water; mp 147°C (from alcohol). IR spectrum: 1719, 1650, 1603, 1570 cm^{-1}. PMR spectrum (in methylene chloride): 2.30 (3H, s, 6-CH_3), 3.35 (2H, s, $-CH_2-$), 7.47 (5H, s, C_6H_5), 9.17 (broadened singlet, COOH). PMR spectrum (in nitromethane): 3.28 (2H, s, $-CH_2-$), 6.13 (1H, s, $=CH-$), 7.48 ppm (5H, s, C_6H_5). Found %: C 68.7; H 5.0. $C_{14}H_{12}O_4$. Calculated %: C 68.8; H 4.9.

The γ-pyrones (IVb-*l*) were obtained similarly with 90-98% yields from the corresponding perchlorates (II-III) (Table 2). The pyrone (IVn) was obtained by heating the oily perchlorate, formed during acid-catalyzed acylation of benzoylpropionic acid by caproic acid, in water.

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