SYNTHESIS OF SUBSTITUTED 2- AND 4-CARBOXYPYRYLIUM SALTS

N. V. Kholodova, Yu. P. Andreichikov,
and G. N. Dorofeenko

UDC 547.81.7.07

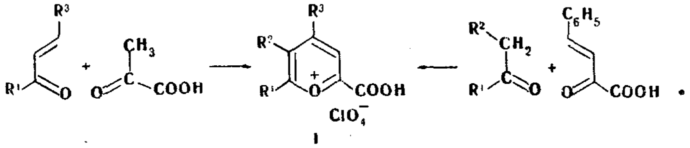
Modified methods for the synthesis of substituted 2- and 4-carboxypyrylium perchlorates and the necessary diphenacylacetic acids are proposed.

The presently known methods for the synthesis of α- and γ-substituted carboxypyrylium salts consist in dehydrogenation of the corresponding carboxypyrans [1, 2], cyclization and oxidative dehydrogenation of diphenacylacetic acids [3], and acid condensation of benzalacetophenone with pyruvic acid [4]. However, these methods are distinguished by their complexity and in most cases are restricted to only particular examples.

In the present paper we propose modified and rather general methods for the synthesis of substituted 2- and 4-carboxypyrylium perchlorates and the necessary diphenacylacetic acids.

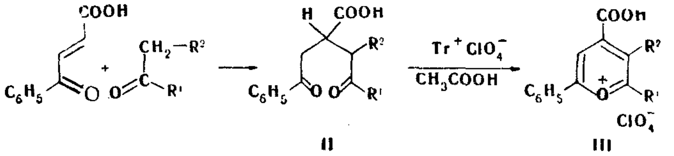
We have found that the simplest method for the preparation of 4,6-diaryl-2-carboxypyrylium salts (Table 1) is the reaction of chalcones with pyruvic acid or its methyl and ethyl esters. Triphenylmethyl perchlorate ($Tr^+ClO_4^-$) in glacial acetic acid was used as the condensing and dehydrogenating agent. Benzalpyruvic acid, which reacts with various ketones to give 2-carboxypyrylium salts, can also be used as the chalcone.

The reaction proceeds via the scheme



Attempts to subject benzalacetone to reaction with pyruvic acid did not lead to the production of 2-carboxypyrylium salts, since benzalacetone undergoes self-condensation to give 2,6-distyryl-4-phenylpyrylium salts; this was confirmed by alternative synthesis from the 2,6-dimethyl-4-phenylpyrylium salt and benzaldehyde. The characteristics of the synthesized 2-styryl-4-phenyl-6-methylpyrylium and 2,6-distyryl-4-phenylpyrylium perchlorates are in agreement with the literature data [5].

4-Carboxypyrylium salts were synthesized by the reaction of benzoylacrylic acid with ketones. However, the yields of the pyrylium salts are low ($\approx$10%) in the case of one-step acid condensation. The rate-determining step of this reaction is probably addition of the ketones to the double bond of benzoylacrylic acid (the Michael reaction). This is confirmed by the fact that carrying out the reaction in two steps — addition of the ketones in an alkaline medium to give diphenacylacetic acids II (Table 2) and subsequent cyclodehydrogenation and aromatization — increases the yields of the 4-carboxypyrylium salts considerably (Table 3).



The 4-unsubstituted 2-carboxypyrylium salt was obtained by condensation of o-hydroxynaphthaldehyde with pyruvic acid in the presence of acetic anhydride and 70% perchloric acid.

Rostov State University. Scientific-Research Institute of Physical and Organic Chemistry, Rostov-on-Don 344006. Translated from Khimiya Geterotsiklicheskikh Soedinenii, No. 2, pp. 162-166, February, 1981. Original article submitted July 9, 1980.

0009-3122/81/1702-0109$07.50

TABLE 1. 2-Carboxypyrylium Perchlorates

Compound	R¹	R²	R³	mp, °C	IR spectrum (characteristic frequencies), cm^{-1}				Found, %			Empirical formula	Calculated, %			Yield, %
					ClO_4	pyrilium ring	C=C	OH	C	H	Cl		C	H	Cl	
Ia	C_6H_5	H	C_6H_5	246—247[a]	1100	1610	1740	3450	57,1	3,8	9,5	$C_{18}H_{13}ClO_7$	57,4	3,5	9,4	65
Ib	C_6H_5	H	p-$NO_2C_6H_4$	169—170[a]	1100	1600	1660	3450	51,5	2,6	8,1	$C_{18}H_{12}ClO_9$	51,2	2,8	8,4	30
Ic	C_6H_5	H	p-$N(CH_3)_2C_6H_4$	237—238[a]	1100	1600	1700	3420	57,0	4,2	8,7	$C_{20}H_{18}ClO_7$	57,2	4,3	8,5	36
Id	C_6H_5	H	p-$CH_3OC_6H_4$	273—274[a]	1080	1630	1740	3500	56,0	4,0	8,8	$C_{19}H_{15}ClO_8$	56,1	3,7	8,7	13
Ie	C_6H_5	H	o-$CH_3OC_6H_4$	280—282[a]	1100	1610	1740	3500	56,1	3,7	8,5	$C_{19}H_{15}ClO_8$	56,1	3,7	8,7	48
If	p-$CH_3OC_6H_4$	H	p-$CH_3OC_6H_4$	330—333[b]	1090	1615	1740	3500	55,0	3,7	8,1	$C_{20}H_{17}ClO_9$	55,0	3,9	8,1	39
Ig	3,4-$(CH_3O)_2C_6H_3$	H	3,4-$(CH_3O)_2C_6H_3$	228—230[a]	1100	1610	1740	3455	52,8	4,6	7,0	$C_{22}H_{23}ClO_{11}$	52,9	4,6	7,1	56
Ih	p-$NO_2C_6H_4$	H	C_6H_5	177—178[a]	1080	1620	1740	3500	51,3	2,9	8,4	$C_{18}H_{12}ClO_9$	51,2	2,8	8,4	16
Ii	p-ClC_6H_4	H	C_6H_5	313—315[c]	1080	1620	1760	3450	52,6	2,9	17,3	$C_{18}H_{12}Cl_2O_7$	52,5	2,9	17,3	36
Ij	p-$CH_3C_6H_4$	H	C_6H_5	258—260[a]	1100	1620	1740	3500	58,8	4,0	8,8	$C_{19}H_{15}ClO_7$	58,4	3,8	9,1	42
Ik	p-$CH_3OC_6H_4$	H	C_6H_5	305—307[b]	1090	1640	1765	3500	56,0	3,7	8,8	$C_{19}H_{15}ClO_8$	56,1	3,7	8,7	45
Il	C_6H_5	CH_3	C_6H_5	250—252[a]	1100	1630	1740	3600	58,2	3,4	9,0	$C_{19}H_{15}ClO_7$	58,4	3,8	9,1	41
Im	3,4-$(CH_3O)_2C_6H_3$	H	C_6H_5	189—190[a]	1090	1605	1705	3500	55,3	4,4	8,2	$C_{20}H_{18}ClO_9$	54,9	4,1	8,1	23
In	α-Naphthyl	H	C_6H_5	178—180[a]	1095	1605	1730	3480	61,9	3,3	8,7	$C_{22}H_{15}ClO_7$	61,9	3,5	8,3	14
Io	C_6H_5	C_6H_5	C_6H_5	180—182[a]	1100	1600	1740	3500	63,7	3,7	7,9	$C_{24}H_{17}ClO_7$	63,6	3,8	7,8	50
Ip	—$(CH_2)_4$—		C_6H_5	223—225[a]	1090	1600	1740	3490	54,2	5,2	10,2	$C_{24}H_{15}ClO_7$	54,1	4,2	10,0	40
Iq	—$(CH_2)_3$—		C_6H_5	170—172[a]	1080	1600	1720	3450	52,7	3,6	10,7	$C_{15}H_{13}ClO_7$	52,9	3,8	10,4	18

---

[a] From glacial acetic acid. [b] From ethanol—nitromethane (2:1). [c] From glacial acetic acid—acetonitrile (2:1). [d] PMR spectrum of Im: 2.3 (3H, s, CH_3), 7.35 (5H, s, C_6H_5), 7.9 (4H, d, C_6H_4), and 8.17 ppm (1H, s, pyrylium ring).

TABLE 2. Diphenacylacetic Acids

Compound	R^1	R^2	mp, °C	Found, %		Empirical formula	Calc., %		Yield, %
				C	H		C	H	
IIa	C_6H_5	H	138—140	72,6	5,4	$C_{18}H_{16}O_4$	72,9	5,4	Quant.
IIb	p-$CH_3OC_6H_4$	H	136—137	69,5	5,5	$C_{19}H_{18}O_5$	69,9	5,5	75
IIc	3,4-$(CH_3O)_2C_6H_3$	H	144—145	67,0	5,4	$C_{20}H_{20}O_6$	67,4	5,6	Quant.
IId	p-ClC_6H_4	H	116—118	65,3	4,4	$C_{18}H_{15}O_4Cl$[a]	65,4	4,5	65
IIe	p-$CH_3C_6H_4$	H	110—113	69,8	5,6	$C_{19}H_{18}O_5$	69,9	5,5	Quant.
IIf	p-BrC_6H_4	H	118—120	57,5	4,0	$C_{18}H_{15}BrO_4$[b]	57,6	4,2	Quant.
IIg	$-(CH_2)_3-$		162—164	69,3	5,9	$C_{15}H_{16}O_4$	69,5	5,8	60
IIh	$-(CH_2)_4-$		129—130	69,9	6,4	$C_{16}H_{18}O_4$	70,0	6,6	83

---

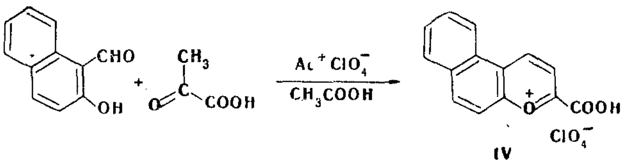
[a] Found: Cl 10.8%. Calculated: Cl 10.6%. [b] Found: Br 21.1%. Calculated: Br 21.3%.

TABLE 3. 4-Carboxypyrylium Perchlorates

Compound	R^1	R^2	mp, °C	IR spectra (characteristic frequencies), cm^{-1}				Found, %			Empirical formula	Calculated, %			Yield, %
				ClO_4	pyrylium ring	C=O	OH	C	H	halogen		C	H	halogen	
IIIa	C_6H_5	H	276—277[a]	1090	1600	1750	3500	57,6	3,8	9,0	$C_{18}H_{13}ClO_7$	57,4	3,8	9,0	76
IIIb[d]	p-$CH_3OC_6H_4$	H	208—210[b]	1090	1600	1785	3440	56,1	3,4	8,5	$C_{19}H_{15}ClO_4$	56,1	3,7	8,7	70
IIIc	3,4-$(CH_3O)_2C_6H_3$	H	223—224[b]	1090	1620	1770	3440	55,1	3,8	8,1	$C_{20}H_{17}ClO_9$	55,0	3,9	8,1	23
IIId[d]	p-$CH_3C_6H_4$	H	281—283[b]	1090	1620	1740	3500	57,0	4,1	8,7	$C_{20}H_{17}ClO_8$	57,1	4,0	8,4	36
IIIe	p-ClC_6H_4	H	255—257[b]	1100	1590	1740	3450	52,7	2,9	17,2	$C_{18}H_{12}Cl_2O_7$	52,5	2,9	17,3	69
IIIf	p-BrC_6H_4	H	297—299[b]	1100	1600	1780	3500	47,5	2,7	25,5	$C_{18}H_{12}ClBrO_7$	47,4	2,6	25,3	65
IIIg	C_6H_5	C_6H_5	248—250[b]	1090	1600	1745	3500	63,6	3,8	7,9	$C_{24}H_{17}ClO_7$	63,6	3,7	7,8	65
IIIh	3,4-$(CH_3O)_2C_6H_3$	3,4-$(CH_3O)_2C_6H_3$	209—210[c]	1090	1590	1750	3450	58,9	4,5	6,2	$C_{28}H_{25}ClO_{11}$	58,7	4,4	6,2	Quant.
IIIi	3,4-$(CH_3O)_2C_6H_3$	p-$CH_3OC_6H_4$	204—205[c]	1090	1590	1750	3450	59,7	4,2	6,5	$C_{27}H_{23}ClO_{10}$	59,6	4,0	6,6	60
IIIj	$-(CH_2)_3-$		299—300[b]	1100	1615	1720	3500	52,7	3,7	10,0	$C_{15}H_{13}ClO_7$	52,9	3,8	10,4	Quant.
IIIk	$-(CH_2)_4-$		240—242[c]	1090	1600	1780	3500	54,0	4,2	9,9	$C_{16}H_{15}ClO_7$	54,2	4,2	10,0	43

---

[a] According to the data in [3], this compound had mp 277°C [from glacial acetic acid—nitromethane (1:1)]. [b] From glacial acetic acid. [c] From ethanol. [d] PMR spectra: IIIb 3.5 (3H, s, CH_3O), 6.87 (5H, s, C_6H_5), 7.8 (4H, d, C_6H_5), and 8.27 ppm (2H, s, pyrylium ring); IIId 2.0 (3H, s, CH_3), 7.47 (5H, s, C_6H_5), 8.0 (4H, d, C_6H_4), and 8.5 ppm (2H, s, pyrylium ring).



IV

The synthesized 2- and 4-carboxypyrylium salts are extremely reactive compounds and have luminescence in organic solvents. However, under the influence of UV light they lose their luminescence properties, probably as a consequence of the facile splitting out of a molecule of acid with the formation of betaine structures.

Further studies of the chemical properties of 2- and 4-carboxypyrylium salts make it possible to hope that they have high reactivity; this is important for the development of new preparative methods in the chemistry of heterocyclic compounds [6, 7].

EXPERIMENTAL

The PMR spectra of solutions of the compounds in trifluoroacetic acid were recorded with a Tesla BS-467 spectrometer (60 MHz) with hexamethyldisiloxane as the internal standard. The IR spectra of mineral oil suspensions of the compounds were recorded with a UR-20 spectrometer.

2-Carboxypyrylium Perchlorates (Ia-q). A mixture of 0.01 mole of the corresponding chalcone, 0.01 mole of pyruvic acid, 0.015 mole of triphenylmethyl perchlorate, and 15 ml of glacial acetic acid was heated for 20 min, after which it was cooled, and the precipitate was removed by filtration, washed with glacial acetic acid and ether, and recrystallized from a suitable solvent (Table 1).

Diphenacylacetic Acids (IIa-h). A 0.015-mole sample of the corresponding ketone was added with stirring in small portions to a mixture of 0.01 mole of benzoylacrylic acid, 1 g of potassium hydroxide, and 10 ml of ethanol, and the mixture was stirred at 30-40°C for 1 h. It was then diluted with ether, and the potassium salt of the diphenylacetic acid was removed by filtration and air dried. The compound was dissolved in water and treated with concentrated HCl at 10°C. The precipitate was removed by filtration, dried, and purified by reprecipitation from alkaline solution by the addition of hydrochloric acid (Table 2).

4-Carboxypyrylium Perchlorates (IIIa-k). A 0.015-mole sample of triphenylmethyl perchlorate was added to a solution of 0.01 mole of the corresponding diphenacylacetic acid in 15 ml of acetic acid, and the mixture was refluxed with stirring for 5 min. It was then cooled, and the product was removed by filtration (Table 3).

2-Carboxynaphtho[2,1-b]pyrylium Perchlorate (IV). A solution of acetyl perchlorate (a mixture of 1 mole of 70% perchloric acid and 3 ml of acetic anhydride) was added to a mixture of 1.72 g (0.01 mole) of 2-hydroxy-1-naphthaldehyde, 10 ml of glacial acetic acid, and 0.1 g of pyruvic acid, and the mixture was heated on a water bath until it turned dark red. It was then cooled and diluted with ether, and the precipitate was removed by filtration, washed with ether, and recrystallized from glacial acetic acid to give 0.4 g (12%) of a product with mp 262°C (dec.). IR spectrum: 1100 (ClO_4^-); 1565, 1605 (aromatic CH); 1720 (C=O); 3520 cm^{-1} (OH). Found: C 52.0; H 3.0; Cl 9.8%. $C_{14}H_9ClO_7$. Calculated: C 51.8; H 2.8; Cl 10.2%.

LITERATURE CITED

1. S. N. Baranov, M. A. Dumbai, and S. V. Krivun, Khim. Geterotsikl. Soedin., No. 10, 1313 (1972).
2. K. Undheim and E. T. Ostenen, Acta Chem. Scand., 27, 1385 (1973).
3. M. Siemiatycki and M. Fugnitto, Bull. Soc. Chim. France, 538 (1961).
4. K. Dimroth, K. Vogel, and W. Krafft, Ber., 101, 2215 (1968).
5. R. Wizinger and K. Wagner, Helv. Chim. Acta, 39, 207 (1956).
6. Yu. P. Andreichikov, N. V. Kholodova, and G. N. Dorofeenko, Khim. Geterotsikl. Soedin., No. 11, 1578 (1975).
7. Yu. P. Andreichikov, N. V. Kholodova, and G. N. Dorofeenko, Dokl. Akad. Nauk SSSR, 236, 1364 (1977).