101. A. Barco, S. Benetti, G. P. Pollini, P. G. Baraldi, D. Simoni, and C. B. Vicentini, J. Org. Chem., 44, 1734 (1979).
102. M. Nitta and A. Yi. Kobayashi, Bull. Chem. Soc. Japan, 58, 991 (1985).
103. M. Nitta and T. Kobayashi, J. Chem. Soc., Perkin I, No. 7, 1401 (1985).
104. H. Kiyima, Y. Nambu, and T. Endo, J. Org. Chem., 50, 1140 (1985).
105. E. B. Koroleva, F. A. Lakhvich, and T. V. Yankova, Khim. Geterotsikl. Soedin., No. 11, 1576 (1987).
106. P. G. Baraldi, A. Barco, S. Benetti, S. Manfredini, G. P. Pollini, and D. Simoni, Tetrahedron Lett., 25, 4313 (1984).
107. G. Lunn, J. Org. Chem., 52, 1043 (1987).
108. A. A. Akhrem, F. A. Lakhvich, and V. A. Khripach, Zh. Obshch. Khim., 45, 2572 (1975).
109. A. A. Akhrem, V. A. Khripach, F. A. Lakhvich, M. I. Zavadskaya, O. A. Drachenova, and I. A. Zorina, Dokl. Akad. Nauk SSSR, 297, 364 (1987).

2-BENZOPYRYLIUM SALTS.

34.* REACTIONS OF 3-CARBOXY-2-BENZOPYRYLIUM SALTS WITH AMINES. SYNTHESIS OF CYCLIC KETOLS

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3-Carboxy-2-benzopyrylium salts form 3-carboxyisoquinolinium salts, their decarboxylated analogs, or products of contraction of the heterocycle, namely, cyclic ketols, depending on the nature of the amine and solvent. Upon treatment with acids, these ketols are demethylated through the intermediate formation of α-acylcarbenium ions and are converted to quinonemethides.

The presence of functional groups in the heterocycle of the pyrylium cation has a definite effect on the nature of its reaction with nucleophiles [2, 3]. Thus, monocyclic α-carboxypyrylium salts react with primary amines to convert to pyridinium salts with decarboxylation [4, 5].

We have found that 1-aryl-3-carboxy-2-benzopyrylium salts Ia and Ib react with primary amines in ethanol or chloroform to give 3-carboxyisoquinolinium salts IIa-IId in 90-97% (method A) and in benzene to give their decarboxylated analogs, IIIa-IIId in 52-62% yield (method A1) [6].

We may propose that salts II are formed as intermediates in benzene and are then converted to III either by thermal decarboxylation [7] or by recyclization due to addition of a nucleophile with simultaneous decarboxylation as found in the case of their monocyclic analogs [5]. However, the direct decarboxylation of isoquinolinium salts IIa-IId under these conditions leads to a sharp decrease in the yields of IIIa-IIId (40-12%, method B). On the other hand, "degenerate recyclization" products were not found in the reaction mixture upon carrying out this reaction with primary amines having substituents at the nitrogen atom different from those in isoquinolinium salts II (method B1) [5, 8]. Thus, if the formation of salts III under the conditions examined proceeds by thermal decarboxylation of acids II, the contribution of this pathway is only slight.

The most likely reason for the different reaction courses lies in the effect of the solvent on the site of nucleophile addition to the 2-benzopyrilium cation, which, in contrast to its monocyclic analogs, has two nonequivalent α-positions. In ethanol, a primary amine, upon addition to $C_{(1)}$, causes recyclization without affecting the carboxyl group. A pyruvic acid enamine fragment capable of facile decarboxylation [9] arises upon addition to $C_{(3)}$ in

*For communication 33, see [1].

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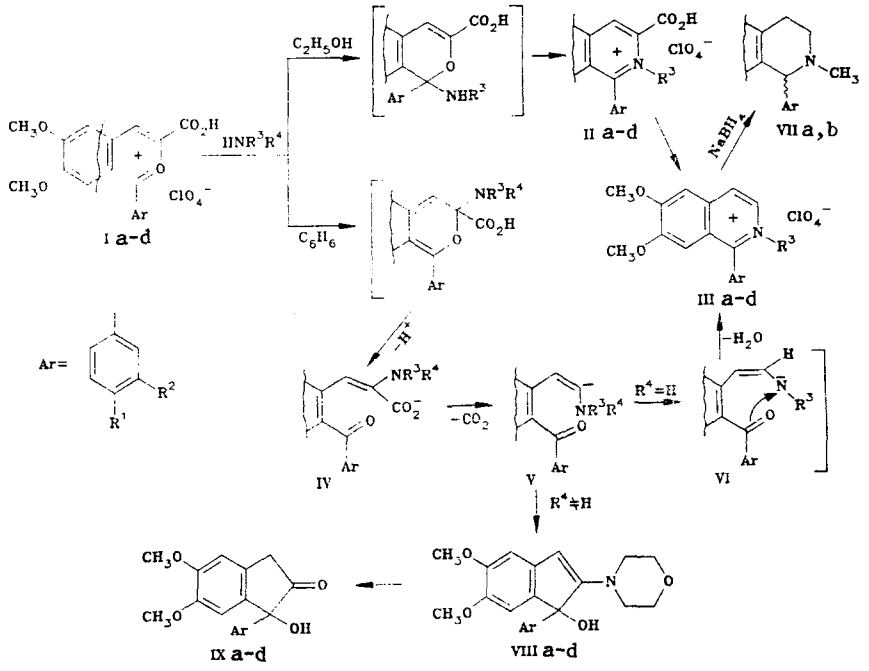
benzene and opening of the heterocycle in IV. The vinyl carbanion V (R^4 = H) formed after the loss of CO_2 is the concealed form of the acyl anion, which is converted to N-anion VI by a prototophic shift. N-Anion VI attacks the carbonyl group with the formation of an isoquinoline ring.

This reaction scheme implies that carbanion V ($R^4 \neq H$), in which prototropic rearrangement is impossible, should be formed after analogous transformations in the reaction of 2-benzopyrylium salts Ia-Id with secondary amines, for which addition at $C_{(3)}$ is also more likely for steric reasons [10]



I, VIII, IX a $R^1=R^2=OCH_3$; b $R^1=OCH_3$, $R^2=H$; c $R^1=R^2=H$; d $R^1=Br$, $R^2=H$; II, III a $R^1=R^2=OCH_3$, $R^3=C_6H_5$; b $R^1=OCH_3$, $R^2=H$, $R^3=C_6H_5$; c $R^1=R^2=OCH_3$, $R^3=CH_3$; d $R^1=OCH_3$, $R^2=H$, $R^3=CH_3$; VII a $R^1=R^2=OCH_3$; b $R^1=OCH_3$, $R^2=H$

On the other hand, the use of secondary amines, which are stronger bases, with a concurrent increase in the reaction temperature for less electrophilic 3-carboxyisoquonolinium salts II, whose decarboxylation proceeds thermally, should markedly increase the yields of III. Indeed, upon heating salts IIa-IId with piperidine or morpholine in xylene, the yield of the decarboxylation products IIIa-IIId reaches 90-97% (method C). The reduction of IIIc in methanol by sodium borohydride gives the racemate of the alkaloid, cryptostilline II (VIIa) in high yield [11].

Heating 2-benzopyrilium salts Ia-Id with morpholine in benzene gave the products of the intramolecular reaction of carbanion V ($R^4 \neq 4$) with the carbonyl group of the benzophenone fragment, namely, ketols IXa-IXd [6]. These ketols were isolated as enamines VIIIa-VIIId, which, however, proved unstable, and, with the exception of VIIIc, are hydrolyzed during their purification by column chromatography on alumina.

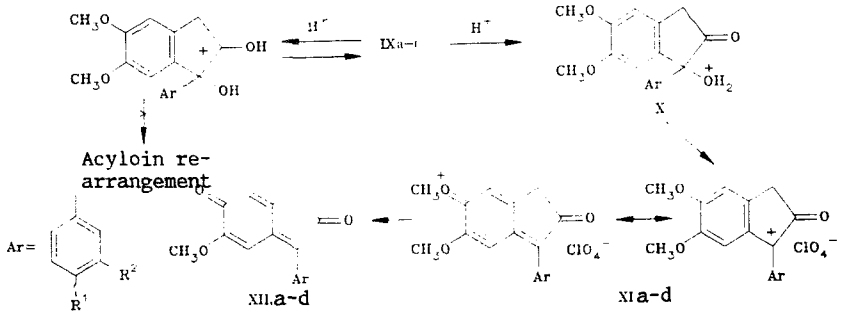
The mass spectrum of IXa shows a molecular ion peak with m/z 344, which corresponds to the molecular formula proposed. The nature of the fragmentation supports the finding of a tetrahedral carbon atom, carbonyl and hydroxyl groups (fragment ions with m/z 328 $[M - O]^+$, 327 $[M - OH]^+$, 299 $[M - CO - OH]^+$, 316, $[M - CO]^+$, and 315 $[M - COH]^+$). These data along with the IR and PMR spectral parameters [6] support the proposed structure for IX.

Highly colored reaction products are formed upon the acid hydrolysis of enamines VIIIa-VIIId instead of colorless ketols IX, which may be obtained by the treatment of solutions of ketols IXa-IXd directly in ethanol.

The IR spectrum of the product obtained from ketol IXa shows a carbonyl band which is shifted to 1710 cm^{-1} relative to 1755 cm^{-1} for the ketol and a new band for a conjugated carbonyl group at 1640 cm^{-1}. The signal for one of the methoxyl groups disappears in the PMR spectrum, while the signal for the methylene group becomes a singlet, indicating the loss of molec-

ular chirality. Furthermore, the mass of the molecular ion (312), which indicates the loss of CH_3OH from the starting ketol and the presence of a weak $[M + 2]^+$ ion peak (m/z 314), characteristic for compounds with quinoid strucutre, permit the assignment of this product as quinonemethide XIIa. The finding that quinoidization proceeded specifically due to demethylation in the fused ring and not in the aryl substituent was supported by the synthesis of compounds with similar spectral characteristics from ketols IXc and IXd.

Oxonium ion X, which is probably formed upon the protonation of ketols IX, loses a water molecule and is converted to carbocation XI, which has an electron-withdrawing carbonyl group at the α-position. This is followed not by deprotonation by analogy to that described by Holland and Jones [12], but rather by demethylation of the 5-methoxy group due to attack of nucleophilic solvent molecules at the conjugated oxonium site.



XI, XII a $R^1=R^2=OCH_3$; b $R^1=OCH_3$, $R^2=H$; c $R^1=R^2=H$; d $R^1=Br$, $R^2=H$

When the reaction was carried out in less nucleophilic acetic acid, carbenium salt XIa, which proved stable at room temperature, was isolated. Upon the action of water or ethanol, XIa is quantitatively converted to quinonemethide XIIa. The carbonyl band in the IR spectrum of salt XIa is found at 1740 cm^{-1}. The PMR spectrum of this compound shows a downfield shift for one of the four methoxyl groups and for the aromatic multiplet; the methylene group signal appears as a singlet.

The great conformational rigidity of α-acylcarbenium ions XIa-XId in comparison with their acyclic analogs [13, 14], due to the presence of the methylene bridge, apparently leads to a marked increase in the contribution of the fused aromatic ring to the resonance stabilization of carbenium ion XI and, thereby, to an increase in its stability.

Thus, the presence of a carboxyl group in the heterocycle of 2-benzopyrylium salts leads to their recyclization by a new pathway, which does not find analogy among other heteroaromatic cations [2]. Either cyclic ketols or quinonemethides may be isolated depending on the type of treatment of the reaction mixture.

EXPERIMENTAL

The IR spectra were taken on a Specord 75 IR spectrophotometer for Vaseline mulls. The PMR spectra were taken on a Tesla BS-487 spectrometer at 80 MHz in $CDCl_3$ and CF_3CO_2H with HMDS as the internal standard. The mass spectra of IXa and XIIa were obtained on a Varian MAT-113 mass spectrometer at 70 eV with direct sample inlet into the source. The elemental analysis data for C, H, N, and Hal corresponded to the calculated values.

3-Carboxy-6,7-dimethoxy-1-phenyl-2-benzopyrylium Perchlorate (Ic, $C_{18}H_{15}ClO_9$). A mixture of 0.5 g (2.2 mmoles) 3,4-dimethoxyphenylpyruvic acid and 0.27 ml (2.6 mmoles) freshly distilled benzaldehyde was heated in 3 ml acetic anhydride until the pyruvic acid was completely dissolved. The solution was cooled and 0.60 ml (7 mmoles) 70% perchloric acid was added dropwise every 5 min at room temperature. The mixture was maintained for 4-5 h. Then, 3 ml ethyl acetate and 2 ml ether were added and left overnight. The precipitate formed was filtered off, washed with ether, and recrystallized from acetic acid to give 0.41 g (45%), mp 254-256°C. IR spectrum: 1740, 1590, 1100 cm^{-1}.

1-(4-Bromphenyl)-3-carboxy-6,7-dimethoxy-2-benzopyrylium perchlorate (Id, $C_{18}H_{14}BrClO_9$) was obtained by analogy in 25% yield as light green crystals with mp 263-264°C (from acetic acid). IR spectrum: 1735, 1605, 1300, 1140 cm^{-1}.

TABLE 1. Characteristics of Isoquinolinium Salts II and III

Compound	Chemical formula	Mp, °C	Synthesis method	Yield, %
II a	$C_{26}H_{24}ClNO_{10}$	253...255	A	93
II b	$C_{25}H_{22}ClNO_9$	239...240	A	95
II c	$C_{21}H_{22}ClNO_{10}$	248...250	A	90
II d	$C_{20}H_{20}ClNO_9$	230...232	A	97
IIIa	$C_{25}H_{24}ClNO_8$	250...252	A1	62
			B1	45
			C	94
IIIb	$C_{24}H_{22}ClNO_7$	235...237	A1	64
			B1	38
			C	98
IIIc	$C_{20}H_{22}ClNO_8$	Разл. 250	A1	52
			B1	18
			C	91
IIId	$C_{19}H_{20}ClNO_7$	230...232	A1	54
			B1	12
			C	98

1-(3,4-Dimethoxyphenyl)-3-carboxy-6,7-dimethoxy-2-phenylisoquinolinium Perchlorate (IIa). A sample of 0.10 ml (1.1 mmole) aniline was added to a suspension of 0.25 g (0.53 mmole) perchlorate Ia in 10 ml ethanol. The solution formed was heated at reflux for 3 h and evaporated. The dark viscous residue was triturated with 5 ml water and 10 drops of 40% perchloric acid. The colorless precipitate was filtered off and washed with a small amount of water. Drying and recrystallization from acetic acid gave 0.27 g salt IIa. IR spectrum: 3300, 1740, 1610, 1180, 1000 cm^{-1}. PMR spectrum (in CF_3CO_2H): 3.36 (s, OCH_3), 3.53 (s, $2OCH_3$), 3.85 (s, OCH_3), 6.57 (d, 3H), 6.77-7.15 (m, 6H), 7.33 (s, 1H), 8.50 ppm (s, 1H).

Products IIb-IId were obtained by analogy (Table 1).

1-(3,4-Dimethoxyphenyl)-6,7-dimethoxy-2-phenylisoquinolinium Perchlorate (IIIa). A1. A sample of 0.1 ml (1.1 mmole) aniline was added to a suspension of 0.23 g (0.45 mmole) perchlorate Ia in 15 ml benzene and heated at reflux for 90 min. The suspension was converted to a viscous mass, which gradually hardened and collected on the bottom of the flask. The reaction mixture was cooled and 10 ml hexane was added. The mixture of solvents was decanted after 30-40 min. The precipitate was triturated with 5 ml water and five drops of 40% perchloric acid were added. The colorless crystalline product was filtered off. Recrystallization from acetic acid gave 0.15 g salt IIIa. IR spectrum: 1605, 1175, 1145, 1095 cm^{-1}. PMR spectrum (in CF_3CO_2H): 3.33 (s, OCH_3), 3.50 (s, $2OCH_3$), 3.77 (s, OCH_3), 6.54-7.22 (m, 10H), 7.88 pppm (s, 2H).

B. A sample of 0.10 ml (1.1 mmole) aniline was added to a suspension of 0.20 g (0.37 mmole) perchlorate IIa in 10 ml benzene. The solution obtained was heated at reflux for 3 h. Salt IIIa was separated as in procedure A1. The product yield was 0.07 g (38%).

B1. A suspension of 0.20 g (0.37 mmole) perchlorate IIa in 10 ml benzene was saturated with gaseous methylamine at room temperature and the solution formed was heated at reflux for 3 h. Salt IIIa was isolated as described in procedure A1.

C. A sample of 0.05 ml (0.6 mmole) piperidine was added to a suspension of 0.10 g (0.18 mmole) perchlorate IIa in 5 ml xylene and heated at reflux for 90 min. After cooling, salt IIIa was isolated as indicated in procedure A1.

Products IIIb-IIId were obtained by analogy (Table 1).

1-(3,4-Dimethoxyphenyl)-2-methyl-6,7-dimethoxy-1,2,3,4-tetrahydroisoquinoline (VIIa). A sample of 1.25 g (33 mmoles) sodium borohydride was added over 15 min in small portions to a solution of 0.30 g (0.68 mmole) salt IIIa in 30 ml methanol and heated at reflux for 20 min. Methanol was distilled off at reduced pressure. The solid residue was treated with 30 ml 10% aq. NaOH and the reaction product was extracted by three 20-ml portions of chloroform. The extract was evaporated to give 0.21 g (85%) VIIa, mp 103°C (from hexane) [11].

Tetrahydroisoquinoline VIIb was obtained by analogy in 89% yield, mp 86-87°C (from hexane).

TABLE 2. Characteristics of 1-Hydroxy-2-indanones (IX) and Quinonemethides (XIIa-d)

Compound	Chemical formula	Mp, °C	IR spectrum, ν, cm^{-1}	Yield, %
IXc	$C_{17}H_{16}O_4$	148...150	3500, 1760, 1605, 1170	74
IXd	$C_{17}H_{15}BrO_4$	174...176	3480, 1765, 1625, 1275	51
XIIa	$C_{18}H_{16}O_5$	200...202	1710, 1640, 1140, 1110	85
XIIb	$C_{17}H_{14}O_4$	187...188	1700, 1635, 1240	76
XIIc	$C_{16}H_{12}O_3$	166...168	1680, 1630, 1215	90
XIId	$C_{16}H_{11}BrO_3$	238...240	1720, 1660, 1265	78

*Characteristics for IXa and IXb were given in our previous work [6].

1-(3,4-Dimethoxyphenyl)-5,6-dimethoxy-1-hydroxyindan-2-one (IXa). A sample of 0.1 ml (1.1 mmole) morpholine was added to a suspension of 0.20 g (0.43 mmole) perchlorate Ia in 15 ml benzene and heated at reflux for 150 min. The benzene solution was decanted from the morpholine perchlorate precipitate and evaporated. The residue was thoroughly triturated in a small amount of chloroform and separated on an alumina column. The fractions containing a product with R_f 0.37 were combined and evaporated. The residue was dissolved in a minimal amount of benzene and hexane was added dropwise until the onset of crystallization to give 0.10 g indanone IXa. Mass spectrum, m/z (relative intensity, %): 165 (100), 166 (14), 179 (21), 227 (5), 241 (10), 254 (17), 255 (11), 269 (40), 270 (14), 284 (14), 285 (98), 286 (33), 299 (24), 300 (10), 301 (30), 315 (70), 316 (94), 317 (22), 327 (5), 328 (20), 344 (M^+, 33).

Products IXb-IXd were obtained by analogy (Table 2).

This reaction with salt Ic gave 1-phenyl-5,6-dimethoxy-2-morpholino-1-hydroxyindene (VIIIc, $C_{21}H_{23}NO_4$) in 75% yield, mp 144-145°C (from benzene). IR spectrum: 3350, 1680, 1610, 1140 cm^{-1}. PMR spectrum (in $CDCl_3$): 0.78 (t, CH_2), 1.15 (s, CH_2), 3.30-3.64 (m, $2CH_2$), 3.68 (s, OCH_3), 3.80 (s, OCH_3), 5.00 (s, OH), 6.78 (s, 1H), 6.95 (s, 1H), 7.10 (s, C_6H_5), 7.23 ppm (s, 1H).

1-(3,4-Dimethoxyphenyl)-6-methoxy-3H-indene-2,5-dione (XIIa). A sample of 0.043 ml (0.52 mmole) 70% perchloric acid was added dropwise to a solution of 0.18 g (0.52 mmole) ketol IXa in 5 ml ethanol. After 10 min, the bright red product was filtered off and washed with a small amount of ethanol. PMR spectrum (in $CDCl_3$): 3.35 (s, CH_2), 3.80 (s, OCH_3), 3.85 (s, $2OCH_3$), 6.41 (s, 1H), 6.70 (s, 1H), 6.93-7.23 ppm (m, 3H). Mass spectrum, m/z (relative intensity, %): 165 (9), 181 (8), 225 (11), 253 (27), 255 (33), 283 (63), 297 (25), 312 (M^+, 100), 314 (14).

Products XIIb-XIId were obtained by analogy (Table 2).

Carbenium salt (XLa, $C_{19}H_{19}ClO_9$). A sample of 0.043 ml (0.52 mmole) 70% perchloric acid was added dropwise to a solution of 0.18 g (0.52 mmole) ketol IXa in 2 ml acetic acid. The solution turned dark blue and black crystals began to precipitate. After 5 min, the reaction product was filtered off, washed with a small amount of absolute ether, and stored at room temperature in a dessicator. The yield was 0.14 g (65%), mp >250°C (dec.). IR spectrum: 1740, 1600, 1260, 1110 cm^{-1}. PMR spectrum (in CF_3CO_2H): 3.55 (s, CH_2), 3.62 (s, $2OCH_3$), 3.70 (s, OCH_3), 4.00 (s, OCH_3), 7.70-7.80 ppm (m, 5H).

LITERATURE CITED

1. Yu. A. Zhdanov, S. V. Verin, I. V. Korobka, and E. V. Kuznetsov, Khim. Geterotsikl. Soedin., No. 9, 1185 (1988).
2. A. T. Balaban, A. Dinculescu, G. N. Dorofeenko, G. W. Fisher, A. V. Koblik, and V. V. Mezheritskii, Pyrylium Salts: Synthesis, Reactions, and Physical Properties, Academic Press, New York (1982), p. 86.
3. V. I. Dulenko, N. N. Alekseev, V. M. Golyak, and L. V. Dulenko, Khim. Geterostikl. Soedin., No. 8, 1137 (1977).
4. N. V. Kholodova, Khim. Geterostikl. Soedin., No. 10, 1428 (1984).
5. A. R. Katritzky, A. Chemprapai, R. C. Patel, and A. Tarraga-Tomas, J. Org. Chem., 47, 492 (1982).

6. V. G. Brovchenko and E. V. Kuznetsov, Khim. Geterotsikl. Soedin., No. 1, 125 (1986).
7. P. A. Klare, General Organic Chemistry [Russian translation], Vol. 8, Izd. Khim., Moscow (1985), p. 280.
8. C. Van der Plas, Khim. Geterotsikl. Soedin., No. 7, 867 (1978).
9. J. K. Stamos, Tetrahedron Lett., 23, 459 (1982).
10. G. P. Safaryan, I. V. Shcherbakova, G. N. Dorofeenko, and E. V. Kuznetsov, Khim. Geterotsikl. Soedin., No. 12, 1608 (1981).
11. S. Agurell, J. Granelli, K. Leander, B. Luning, and J. Rosenblom, Acta, Chem. Scand., Ser. B, 28, 239 (1974).
12. J. M. Holland and D. W. Jones, J. Chem. Soc., C, No. 3, 608 (1971).
13. M. Maleni and A. C. Hopkinson, Tetrahedron Lett., 24, 4911 (1983).
14. K. Takeuchi, T. Kitagawa, and K. Okamoto, Chem. Commun., No. 1, 7 (1983).

PHOTOCHEMICAL REACTIONS OF 7-AMINOCOUMARINS.

4.* REACTION OF 4-METHYL-7-DIETHYLAMINOCOUMARIN WITH COMPOUNDS TENDING TO PHOTOLYTIC DISSOCIATION

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The photochemical reactions of 4-methyl-7-diethylaminocoumarin with a series of alkyl halides including isopropyl iodide, allyl iodide, bromoacetone α-bromoethyl acetate, phenacyl bromide, p-bromophenacyl bromide, and chloroacetonitrile, and aryl iodides including iodobenzene, 2-nitroiodobenzene, 3,4-dimethoxyiodobenzene, and 3-iodo-4-methyl-7-diethylaminocoumarin proceed by a radical addition mechanism to give 3-substituted aminocoumarins. A series of 3-substituted 7-aminocoumarins was also obtained as a result of the photochemical reactions of 4-methyl-7-diethylaminocoumarin, with other reagents, having photolabile chemical bonds such as dioxanyl peroxide, phenyl iodosodiacetate, and nitromethane. The luminescence characteristics of the compounds synthesized were studied.

We have previously reported about the [2 + 2] photocycloaddition reactions of 7-aminocoumarins [2, 3] and unusual photoreactions of 4-methyl-7-diethylaminocoumarin (I) with unsaturated compounds, which affect the diethylamino group [1]. In the present article, we describe the photochemical reactions of coumarin I with alkyl and aryl halides and some other compounds, which tend to undergo photolytic dissociation.

7-Dialkylaminocoumarins lose alkyl groups at the nitrogen atom upon irradiation in nitroaromatic solvents [4]. The dealkylation also proceeds upon the photooxidation of dialkylaminocoumarins by atmospheric oxygen, which attacks the α-position relative to the nitrogen atom or the alkyl group at $C_{(4)}$ [5, 6]. Since these processes occur with the formation of radical intermediates [5], we might expect that coumarin I would also react with other compounds, which are potential radical sources in photochemical reactions. A priori, two primary directions for the radical reactions may be proposed for coumarin I: loss of a hydrogen atom from 4-methyl group or from the methylene group in the α-position to the nitrogen atom. Addition or substitution reactions at the $C_{(3)}$—$C_{(4)}$ bond also appeared to be probable.

We initially studied the reaction of the starting coumarin with alkyl halides, which tend to act as acceptors in electron transfer processes [7] and also give direct dissociation of C—Hal bonds by the action of short-wavelength UV light. A preliminary comparison of the reactivity of alkyl halides in the series RCl→RBr→RI showed that the use of alkyl iodides is best from the preparative viewpoint relative to coumarin upon irradiation by the full light of a PRK-2 mercury lamp, while, in the case of functionally substituted compounds, alkyl bromides,

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