One-pot Synthesis of New 3-Substituted Coumarins by Tandem Reactions

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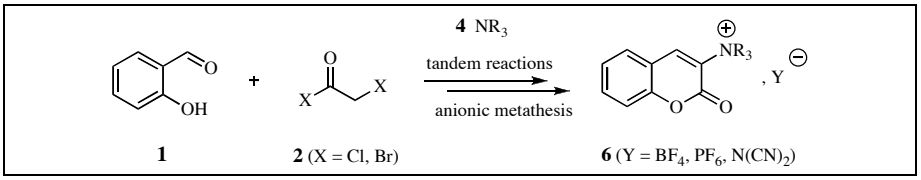
Received December 8, 2005



The synthesis of new 3-substituted coumarins appended to imidazolium, pyridinium, 3-dimethylamino pyridinium, 3-chloro pyridinium and 3-bromo pyridinium salts is reported. These salts were prepared by tandem reactions, followed by quantitative anionic metathesis. The structure of these new 3-substituted coumarins was established by NMR (^{1}H, ^{13}C) and high-resolution mass spectrometry.

J. Heterocyclic Chem., **44**, 193 (2007).

INTRODUCTION

Coumarins occupy a unique place in the realm of natural and synthetic organic chemicals, which present a wide variety of properties [1]. Members of this group display a broad range of applications as additives to perfumes and cosmetics [2], as photographic sensitizers and solar collectors [3], as fluorescent markers in biochemistry [4], as tuneable dye lasers [5]. Since the 1990's, a large number of *in vivo* and *in vitro* studies have revealed a diverse array of pharmacological and biochemical properties like antibacterial [6], inhibitory properties on human platelet aggregation [7], anti-HIV activity [8], antimutagenic and antitumor activities [9]. Coumarins are also exploited as intermediates and building blocks in organic chemistry [10].

For the preparation of coumarins and their derivatives, various methods have been used, which include Perkin [11], Wittig [12], Knoevenagel [13], Reformatsky [14] and Pechmann [15] reactions and more recently palladium-catalyzed carbonylative annulations [16].

During the last few years, there has been great interest in 3-substituted coumarins (*i.e.* 3-carboxy coumarins [13b], 3-ethoxycarbonyl coumarins [13c], 3-tetrahydrothiophenium coumarins [17], 3-phenoxy coumarins [18]) that have been used to synthesize modified cephalosporins [19], penicillins [20] and fluorescent chromophores [21]. Continuing our work on imidazolium and pyridinium salts in ionic liquid chemistry [22], we decided to investigate the synthesis of coumarins substituted in C-3 position by imidazolium or pyridinium moiety. Herein, we report the results obtained for the synthesis of new coumarins. Preparative procedures including characterization (^{1}H, ^{13}C, HRMS) are also presented.

RESULTS AND DISCUSSION

The starting 2-(halogenoacetoxy) benzaldehydes **3a,b** (X = Cl, Br) were readily obtained by modification of the procedure of Fuson *et al*. [23] from salicylaldehyde **1** and chloroacetyl chloride **2a** or bromoacetyl bromide **2b** in dichloromethane at room temperature (Scheme I) with pyridine. After work-up and purification by distillation, the 2-(chloroacetoxy) benzaldehyde **3a** and 2-(bromoacetoxy)benzaldehyde **3b** were isolated respectively in 78 and 82% yield.

With the desired aldehydes **3a,b** in hand, we have examined the synthesis of coumarins **5** by cyclization of **3** with various N-nucleophiles **4** (*i.e.* methyl imidazole **4a**, pyridine **4b**, 4-dimethylamino pyridine **4c**, 3-chloro pyridine **4d**, 3-bromo pyridine **4e**). For the preparation of salts **5**, we have developed a one-pot tandem reaction by addition of a solution of nucleophile **4** in dichloromethane to the 2-(halogenoacetoxy)benzaldehydes **3a,b**. After refluxing (4 - 48 hours) followed by addition of ethanol in the crude reaction mixture at room temperature, the precipitated salts **5** could then be isolated by simple filtration after washings with the appropriate solvent (Et_2O, AcOEt). The formation of salt **5** by tandem reactions could be attributed to a nucleophilic substitution between the starting product **3** and **4** which gave the intermediate **A** in the first step, followed by intramolecular condensation of the active methylene with the formyl group. Initial attempts to isolate the intermediate salt **A** during the tandem reactions were unsuccessful. The salts **5(a-j)** were characterized by conventional techniques (^{1}H, ^{13}C NMR) and the purity was controlled by high-

resolution mass spectrometry. The results summarized in Table I show that 2-(halogenoacetoxy)benzaldehydes **3** react with various nucleophiles **4** to give the 3-substituted coumarins **5** in yield ranging from 30 to 88% (Table I). Analysis of the results in Table I show that the choice of the nucleophilic compound **4** and/or the 2-(halogeno-acetoxy)benzaldehydes **3** controls the nucleophilic substitution versus annulation pathway. In general, the experimental results can be divided into two groups, those that gave low or moderate yields (**5a**: 49%, **5g**: 30% and **5i**: 35%) from 2-(chloroacetoxy)benzaldehyde **3a** with **4a**, **4d** or **4e** and, those that afforded good yields from 2-(bromoacetoxy)benzaldehyde **3b**. In the first case, the nucleophilic substitution in the tandem reaction was less favoured with the 2-(chloroacetoxy)benzaldehyde **3a**. Structural assignment of the compounds **5(a-j)** is based on spectroscopic data (^{1}H, ^{13}C NMR). For example, in the ^{1}H and the ^{13}C NMR spectrum of **5a** in D_2O solution, the singlet of H-4 appears at high field (δ_{H-4} 8.36 ppm) and two signals at δ_{C-3} 117.40 and δ_{C-4} 138.67 ppm that were assigned to the intracyclic double bond.

In the last step for the preparation of salts **6** by anion-exchange reactions, the corresponding weakly coordinating anions used were BF_4^-, PF_6^- and $N(CN)_2^-$ from the respective commercially available starting salts NH_4BF_4, KPF_6 and $NaN(CN)_2$. All the anion-exchange reactions were carried out in dry acetonitrile stirred at 70°C under nitrogen for 24 hours. Then the insoluble salt (NH_4X, KX or NaX with X = Cl, Br) was filtered off and then dissolved in de-ionized water. The efficiency of the metathesis reaction was determined by measuring the chloride or bromide ion solution using the Mohr's method [24]. After filtration of the crude reaction mixture of **6** on a pad of Celite® to remove halide contaminants trapped in the salt, followed by elimination of MeCN *in vacuo*, the salts **6** (Table II) were isolated in good yields (89 – 98%). The potential halide impurities in salts **6** were evaluated by volumetric titration using a modified Volhard's method [25] developed in our laboratory (halide < 100 ppm).

Scheme I

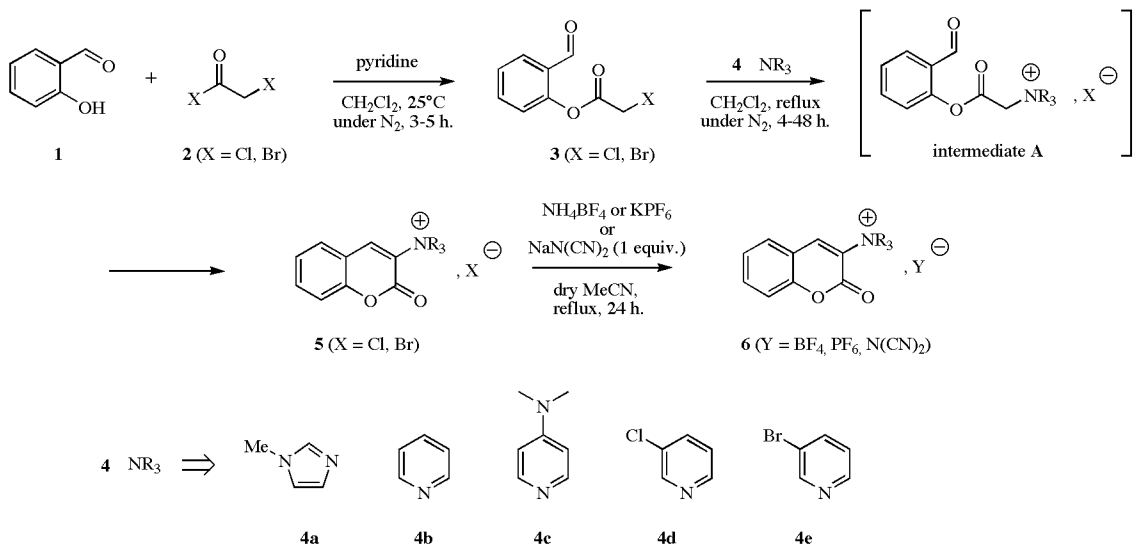


Table I

Product **5**	X	Starting **4**	Yield of **5** (%)[a]	Melting point (°C)
5a	Cl	**4a**	49	250-252
5b	Br	**4a**	62	262-264
5c	Cl	**4b**	88	220-222
5d	Br	**4b**	82	214-215
5e	Cl	**4c**	78	245-247
5f	Br	**4c**	78	235-237
5g	Cl	**4d**	30	225-227
5h	Br	**4d**	88	230-232
5i	Cl	**4e**	35	> 260
5j	Br	**4e**	69	> 260

[a] Yield of isolated product.

Table II

Product **6**	Y^-	Starting salt **5**	Yield of **6** (%)[a]	Melting point (°C)
6a	BF_4	**5a** or **5b**	89	224-226
6b	PF_6	**5a** or **5b**	92	260-262
6c	$N(CN)_2$	**5a** or **5b**	98	171-176
6d	BF_4	**5c** or **5d**	96	> 260
6e	PF_6	**5c** or **5d**	97	> 260
6f	$N(CN)_2$	**5c** or **5d**	89	219-221
6g	BF_4	**5e** or **5f**	98	250-252
6h	PF_6	**5e** or **5f**	96	> 260
6i	$N(CN)_2$	**5e** or **5f**	95	210-212
6j	BF_4	**5g** or **5h**	98	220-222
6k	PF_6	**5g** or **5h**	97	240-242
6l	$N(CN)_2$	**5g** or **5h**	99	210-212

Table II (continued)

Product **6**	Y^-	Starting salt **5**	Yield of **6** (%)[a]	Melting point (°C)
6m	BF_4	**5i** or **5j**	99	224-226
6n	PF_6	**5i** or **5j**	98	> 260
6o	$N(CN)_2$	**5i** or **5j**	99	220-222

[a] Yield of isolated product.

EXPERIMENTAL

General. Melting points were determined on a Kofler melting point apparatus and were uncorrected. ^{1}H NMR spectra were recorded on BRUKER AC 300 P (300 MHz) and BRUKER ARX 200 (200 MHz) spectrometers, ^{13}C NMR spectra on BRUKER AC 300 P (75 MHz) spectrometer. Chemical shifts are expressed in parts per million downfield from tetramethylsilane as an internal standard. Data are given in the following order: *δ* value, multiplicity (s, singlet; d, doublet; t, triplet; q, quartet; m, multiplet; br, broad), number of protons, coupling constants *J* is given in Hertz. The mass spectra (HRMS) were taken respectively on a MS/MS ZABSpec TOF Micromass (EBE TOF geometry) at an ionizing potential of 8 eV for the salts **5** and **6** and on a VARIAN MAT 311 at an ionizing potential of 70 eV for the other compounds in the Centre Régional de Mesures Physiques de l'Ouest (CRMPO, Rennes). Acetonitrile was distilled over calcium chloride after standing overnight and stored over molecular sieves (3Å). Solvents were evaporated with a BUCHI rotary evaporator. All reagents were purchased from Acros, Aldrich Chimie, Fluka France and used without further purification.

Standard Procedure for the Synthesis of 2-(Chloroacetoxy)-benzaldehyde (3a) and 2-(Bromoacetoxy)benzaldehyde (3b). All these reactions were carried out under a nitrogen atmosphere. To a solution of salicylic aldehyde (**1**) (2 g, 16.37 mmoles) and dry pyridine (1.62 g, 20.47 mmoles) in 30 ml of dry methylene chloride was added dropwise chloroacetyl chloride (**2a**) (2.29 g (20.30 mmoles) or bromoacetyl bromide (**2b**) (4.09 g, 20.30 mmoles) over 20 minutes and under vigorous magnetic stirring at 0°C. The reaction mixture was stirred for 5 hours (from **2a**) or 3 hours (from **2b**) at room temperature. After elimination of the insoluble pyridinium salt on a filter paper, 20 ml of a 0.1 *M* of chlorhydric acid were added in the crude reaction mixture. After decantation, the aqueous layer was washed with methylene chloride (2 x 10 ml) then, the resulting organic layer was washed successively with 20 ml of saturated sodium hydrogenocarbonate, 10 ml of deionized water and was dried over magnesium sulphate. The organic solution was concentrated by rotary evaporation under reduced pressure and the crude reaction mixture was purified by distillation with a BÜCHI B-585 microdistillator.

2-(Chloroacetoxy)benzaldehyde (**3a**). Yield 78% (*Litt.* [17] 36%), bp 120°C/0.5 Torr. ^{1}H nmr ($CDCl_3$): δ 4.18 (s, 2H, CH_2), 7.20 (dd, 1H, J = 8.1, 0.9 Hz, H-3, Ar), 7.41 (td, 1H, J = 7.5, 1.03 Hz, H-5, Ar), 7.63 (td, 1H, J = 7.7, 1.8 Hz, H-4, Ar), 7.83 (dd, 1H, J = 7.5, 1.8 Hz, H-6, Ar), 10.02 (s, 1H, CHO). ^{13}C nmr ($CDCl_3$): δ 40.88 (t, J = 155 Hz), 123.20 (dd, J = 165, 7.1 Hz, C-3), 127.06 (dd, J = 165, 7.1 Hz, C-5), 127.64 (dm, J = 26 Hz, C-1), 132.64 (dd, J = 162, 9 Hz, C-6), 135.53 (dd, J = 164, 8.1 Hz, C-6), 150.30 (m, C-2), 165.91 (m, CO), 189.04 (dd, J = 180, 5 Hz, CHO). hrms, m/z 198.0081 found (calculated for $C_9H_7O_3{}^{35}Cl$, M^+ requires 198.0084). *Anal.* Calcd. for $C_9H_7ClO_3$: C, 54.43; H, 3.55; Cl, 17.85; O, 24.17. Found: C, 54.45, H, 3.52; Cl, 17.83, O, 24.2.

2-(bromoacetoxy)benzaldehyde (**3b**). Yield 82%, bp 125°C/0.5 Torr, ^{1}H nmr ($CDCl_3$): 4.17 (s, 2H, CH_2), 7.22 (dd, 1H, J = 8.2, 0.8 Hz, H-3, Ar), 7;43 (td, 1H, J = 7.6, 0.8 Hz, H-5, Ar), 7.65 (td, 1H, J = 8, 1.8 Hz, H-4, Ar), 7.88 (dd, 1H, J = 7.6, 1.8 Hz, H-6, Ar), 10.09 (s, 1H, CHO). ^{13}C nmr ($CDCl_3$): δ 25.37 (t, J = 154 Hz), 123.06 (dd, J = 165, 8 Hz, C-3), 126.99 (dd, J =165, 8 Hz, C-5), 127.76 (dm, J = 24 Hz, C-1), 131.97 (dd, J = 162, 9 Hz, C-6), 135.44 (dd, J = 164, 9 Hz, C-6), 150.67 (m, C-2), 165.59 (m, CO), 188.73 (dd, J = 180, 5 Hz, CHO). hrms, m/z 241.9773 found (calculated for $C_9H_7O_3{}^{79}Br$, M+ requires 241.9779). *Anal.* Calcd. for $C_9H_7BrO_3$: C, 44.47; H, 2.90; Br, 32.87; O, 19.75. Found: C, 44.41, H, 2.95; Cl, 32.86, O, 19.78.

Standard Procedure for the Synthesis of Compounds (**5a**) **and** (**5b**). These reactions were carried out under a nitrogen atmosphere. To the 2-(chloroacetoxy)benzaldehyde (**3a**) (1 g, 5.04 mmoles) or to the 2-(bromoacetoxy)benzaldehyde (**3b**) (1g, 4.11 mmoles) was added dropwise over 15 minutes a solution of *N*-methyl imidazole (**4a**) (0.17 g, 5.04 mmoles) for the preparation of salt (**5a**) or (0.5 g, 6.17 mmoles) for (**5b**) in dry methylene chloride (20 ml) under vigorous magnetic stirring at 41°C. After cooling down to room temperature, ethanol (20 ml) was added in the reaction mixture and a solid was obtained after 15 minutes of stirring. The precipitated salt (**5**) was collected by filtration, washed with diethylether (2 x 5 ml) and dried under reduced pressure (10-2 Torr) during 2 hours. The compound (**5**) was stored in the dark under an inert atmosphere.

1-Methyl-3-(2-oxo-4a,8a-dihydro-2*H*-chromen-3-yl)imida-zolium chloride (**5a**). Yield 49%. White needles, mp 250-252°C. ^{1}H nmr (D_2O): δ 3.95 (s, 3H, Me), 7.36 (td, 2H, J = 8.3 Hz, H-6', H-8', Ar), 7.59 (s, 1H, H-4), 7.68 (td, 2H, J = 7.8 Hz, H-5', H-7', Ar), 7.79 (s, 1H, H-5), 8.36 (s, 1H, H-4', Ar), 9.25 (s, 1H, H-2, Ar). 13C nmr (D_2O): δ 36.35 (q, J = 145 Hz), 116.57 (dd, J = 160, 6 Hz, C-8'), 117.44 (m, C-3'), 120.96 (m, C-4a'), 122.28 (dm, J = 200 Hz, C-5), 123.84 (ddd, J = 200, 12, 5 Hz, C-4), 126.00 (m, C-5'), 129.63 (dm, J = 168 Hz, C-6'), 134.16 (dm, J = 160 Hz, C-7'), 137,03 (dm, J = 225 Hz, C-2), 138.74 (dd, J = 169, 5 Hz, C-4'), 152.52 (m, C-8a'), 158;30 (d, J = 8 Hz, CO). hrms, m/z 227.0821 found (calculated for $C_{13}H_{11}N_2O_2$, C^+ requires 227.0821).

1-Methyl-3-(2-oxo-4a,8a-dihydro-2*H*-chromen-3-yl)imida-zolium bromide (**5b**). Yield 62%. White needles, mp 262-264°C. 1H nmr (D_2O): δ 4.69 (s, 3H, Me), 7.35 (td, 2H, J = 8.4 Hz, H-6', H-8', Ar), 7.61 (s, 1H, H-4), 7.69 (td, 2H, J = 7.9 Hz, H-5', H-7', Ar), 7.80 (s, 1H, H-5), 8.36 (s, 1H, H-4', Ar), 9.27 (s, 1H, H-2). ^{13}C nmr (D_2O): δ 36.44 (q, J = 145 Hz), 116.56 (dd, J = 160, 6 Hz, C-8'), 117.40 (m, C-3'), 120.90 (m, C-4a'), 122.31(dm, J = 200 Hz, C-5), 123.94 (ddd, J = 200, 12, 5 Hz, C-4), 126.03 (m, C-5'), 129.65 (dm, J = 168 Hz, C-6'), 134.17 (dm, J = 160 Hz, C-7'), 136.98 (dm, J = 225 Hz, C-2), 138.67 (dd, J = 169, 5 Hz, C-4'), 152.47 (m, C-8a'), 158.18 (d, J = 8 Hz, CO). hrms, m/z 227.0821 (calculated for $C_{13}H_{11}N_2O_2$, C+ requires 227,0821).

1-(2-Oxo-4a,8a-dihydro-2*H*-chromen-3-yl)pyridinium chloride (**5c**). The compound (**5c**) was prepared from 2-(chloroacetoxy)benzaldehyde (**3a**) (1 g, 5.04 mmoles) and dry pyridine (0.4 g, 5.04 mmoles) according to the experimental procedure used for (**5a**) after a reaction time of 24 hours under reflux and washings with ethyl acetate (3 x 20 ml). This compound was obtained as white needles, mp 220-222°C and 88% yield. ^{1}H nmr (D_2O): δ 7.45 (t, 2H, J = 7.6 Hz, H-6', H-8'),

7,78 (dd, 2H, J = 14.2, 7.8 Hz, H-5', H-7'), 8.22 (t, 2H, J = 7 Hz, H-3, H-5), 8.60 (s, 1H, H-4'), 8.79 (t, 1H, J = 7.8 Hz, H-4), 9.02 (d, 2H, J = 5.4 Hz, H-2, H-6). ^{13}C nmr (D_2O): δ 116.86 (dd, J = 165, 6 Hz, C-8), 117.36 (m, C-3'), 126.24 (dm, J = 9 Hz, C-6'), 128.08 (dm, J = 171 Hz, C-4a'), 128.37 (m, C-5'), 130.38 (m, C-3, C-5), 135.22 (dm, J = 165 Hz, C-7'), 142.66 (dd, J = 171, 6 Hz, C-2, C-6), 145.35 (dm, J = 185 Hz, C-4), 148.48 (m, C-4'), 153.41 (m, C-8a'), 158.34 (d, J = 8 Hz, CO). hrms, m/z 224.0713 found (calculated for $C_{14}H_{10}NO_2$, C^+ requires 224.0712).

1-(2-Oxo-4a,8a-dihydro-2*H*-chromen-3-yl)pyridinium bromide (**5d**). The compound (**5d**) was prepared from 2-(bromoacetoxy)benzaldehyde (**3b**) (1 g, 4.11 mmoles) and dry pyridine (0.32 g, 4.11 mmoles) according to the experimental procedure used for (**5b**) after a reaction time of 24 hours under reflux and washings with ethyl acetate (3 x 20 ml). This compound was obtained as white needles, mp 214-216°C and 82% yield. ^{1}H nmr (D_2O): δ 7.46 (t, 2H, J = 7.8 Hz, H-6', H-8'), 7.79 (dd, 2H, J = 14.2, 7.8 Hz, H-5', H-7'), 8.22 (t, 2H, J = 7.1 Hz, H-3, H-5), 8.59 (s, 1H, H-4'), 8.70 (t, 1H, J = 6.7 Hz, H-4), 9.00 (d, 2H, J = 5.9 Hz, H-2, H-6). ^{13}C nmr (D_2O): δ 116.87 (dd, J = 165, 6 Hz, C-8'), 117.37 (m, C-3'), 126.24 (dm, J = 9 Hz, C-6'), 127.97 (dm, J = 171 Hz, C-4a'), 128.37 (m, C-5'), 130.37 (m, C-3, C-5), 135.22 (dm, J = 165 Hz, C-7'), 142.66 (dd, J = 171, 6 Hz, C-2, C-6), 145.36 (dm, J = 185 Hz, C-4), 148.47(m, C-4'), 153.43 (m, C-8a'), 158.37 (d, J = 8 Hz, CO). hrms, m/z 224.0714 found (calculated for $C_{14}H_{10}NO_2$, C^+ requires 224.0712).

4-Dimethylamino-1-(2-oxo-4a,8a-dihydro-2*H*-chromen-3-yl)pyridinium chloride (**5e**). The compound (**5e**) was prepared from 2-(chloroacetoxy) benzaldehyde (**3a**) (1 g, 5.04 mmoles) and 4-dimethylamino pyridine (0.61 g, 5.04 mmoles) according to the experimental procedure used for (**5a**) after a reaction time of 4 hours under reflux. This compound was obtained as white needles, mp 245-247°C and 78% yield. ^{1}H nmr (D_2O): δ 3.18 (s, 6H, Me), 6.88 (d, 2H, J = 7.9 Hz, H-3, H-5), 7.32 (td, 2H, J = 7.3 Hz, H-6', H-8'), 7.62 (t, 2H, J = 7.2 Hz, H-5', H-7'), 8.01 (d, 2H, J = 7.8 Hz, H-2, H-6), 8.26 (s, 1H, H-4'). ^{13}C nmr (D_2O): δ 40.02 (C-8, C-9), 107.55 (C-8'), 116.53(C-6'), 117.67 (C-5'), 126.03 (C-3'), 127.08 (C-7'), 129.68 (C-4a'), 134.10 (C-3, C-5), 140.07 (C-2, C-6), 141.06 (C-4'), 152.55 (C-4), 156.62 (C-8a'), 158.92 (CO). hrms, m/z: 267.1139 found (calculated for $C_{16}H_{15}N_2O_2$, C^+ requires 267.1134).

4-Dimethylamino-1-(2-oxo-4a,8a-dihydro-2*H*-chromen-3-yl)-pyridinium bromide (**5f**). The compound (**5f**) was prepared from 2-(bromoacetoxy)benzaldehyde (**3b**) (1 g, 4.11 mmoles) and 4-dimethylamino pyridine (0.5 g, 4.11 mmoles) according to the experimental procedure used for (**5b**) after a reaction time of 3 hours under reflux. This compound was obtained as white needles, mp 235-237°C and 78% yield. ^{1}H nmr (D_2O): δ 3.20 (s, 6H, Me), 6.94 (d, 2H, J = 7.9 Hz, H-3, H-5), 7.40 (d, 2H, J = 6.9 Hz, H-6', H-8'), 7.67 (t, 2H, J = 7.5 Hz, H-5', H-7'), 8.05 (d, 2H, J = 7.8 Hz, H-2, H-6), 8.28 (s, 1H, H-4'). ^{13}C nmr (D_2O): δ 39.88 (C-8, C-9), 107.50 (C-8'), 116.60 (C-6'), 117.79 (C-5'), 125.99 (C-3'), 127.32 (C-7'), 129.63 (C-4a'), 134.08 (C-3, C-5), 140.32 (C-2, C-6), 141.11 (C-4'), 152.73 (C-4), 156.76 (C-8a'), 159.37 (CO). hrms, m/z 267.1134 found (calculated for $C_{16}H_{15}N_2O_2$, C^+ requires 267.1134).

3-Chloro-1-(2-oxo-4a,8a-dihydro-2*H*-chromen-3-yl)pyridinium chloride (**5g**). The compound (**5g**) was prepared from 2-(chloroacetoxy)benzaldehyde (**3a**) (1 g, 5.04 mmoles) and 3-chloro pyridine (0.57 g, 5.04 mmoles) according to the experimental procedure used for (**5a**) after a reaction time of 48 hours under reflux and washings with ethyl acetate (2 x 20 ml). This compound was obtained as beige needles, mp 225-227°C and 30% yield. ^{1}H nmr (D_2O): δ 7.45 (d, 2H, J = 7.2 Hz, H-6', H-8'), 7.80 (t, 2H, J = 7.6 Hz, H-5', H-7'), 8.24 (t, 1H, J = 8.5 Hz, H-5), 8.65 (s, 1H, H-4'), 8.76 (d, 1H, J = 8.3 Hz, H-4), 9.04 (d, 1H, J = 7 Hz, H-6), 9.27 (s, 1H, H-2). ^{13}C nmr (D_2O): δ 116.86 (C-8'), 117.26 (C-3'), 126.35 (C-6'), 127.56 (C-4a'), 128.83 (C-5'), 130.61 (C-7'), 135.48 (C-5), 136.06 (C-3), 142.98 (C-4), 144.09 (C-6), 144.65 (C-2), 148.25 (C- 4'), 153.51 (C-8a'), 157.88 (CO). hrms, m/z 258.0328 found (calculated for pour $C_{14}H_9NO_2{}^{35}Cl$, C^+ requires 258.0322).

3-Chloro-1-(2-oxo-4a,8a-dihydro-2*H*-chromen-3-yl)pyridinium bromide (**5h**). The compound (**5h**) was prepared from 2-(bromoacetoxy)benzaldehyde (**3b**) (1 g, 4.11 mmoles) and 3-chloro pyridine (0.47 g, 4.11 mmoles) according to the experimental procedure used for (**5b**) after a reaction time of 12 hours under reflux and washings with ethyl acetate (2 x 20 ml). This compound was obtained as yellow needles, mp 235-237°C and 80% yield. ^{1}H nmr (D_2O): δ 7.47 (d, 2H, J = 7.1 Hz, H-6', H-8'), 7.81 (t, 2H, J = 7.5 Hz , H-5', H-7'), 8.26 (t, 1H, J = 8.3 Hz, H-5), 8.63 (s, 1H, H-4), 8.78 (d, 1H, J = 8.5 Hz, H-4'), 9.02 (d, 1H, J = 5.9 Hz, H-6), 9.28 (s, 1H, H-2). ^{13}C nmr (D_2O): δ 116.91 (C-8'), 117.23 (C-3'), 126.33 (C-6'), 127.50 (C-4a'), 128.83 (C-5'), 130.53 (C-7'), 135.51 (C-5), 136.03 (C-3), 142.95 (C-4), 144.08 (C-6), 144.62 (C-2), 148.20 (C- 4'), 153.50 (C-8a'), 157.92 (CO). hrms, m/z 258.0328 found (calculated for pour $C_{14}H_9NO_2{}^{35}Cl$, C+ requires 258.0322).

3-Bromo-1-(2-oxo-4a,8a-dihydro-2*H*-chromen-3-yl)pyridinium chloride (**5i**). The compound (**5i**) was prepared from 2-(chloroacetoxy)benzaldehyde (**3a**) (1 g, 5.04 mmoles) and 3-bromo pyridine (0.79 g, 5.04 mmoles) according to the experimental procedure used for (**5a**) after a reaction time of 24 hours under reflux. This compound was obtained as beige needles, mp > 260°C and 35% yield. ^{1}H nmr ($(D_3C)_2SO$): δ 7.52 (t, 2H, J = 7.3 Hz, H-6', H-8'), 7.85 (t, 2H, J = 6.8 Hz , H-5', H-7'), 8.18 (s, 1H, H-5), 8.67 (s, 1H, H-4'), 8.99 (d, 1H, J = 8.4 Hz, H-4), 9.16 (d, 1H, J = 6 Hz, H-6), 9.52 (s, 1H, H-2). ^{13}C nmr ($(D_3C)_2SO$): δ 117.07 (C-8'), 117.59 (C-3'), 122.63 (C-4a'), 126.42 (C-6'), 128.16 (C-3), 129.06 (C-5'), 130.89(C-7'), 135.41 (C-5), 141.96 (C-4), 145.02 (C-6), 146.81 (C-2), 150.97 (C- 4'), 153.61 (C-8a'), 156.95 (CO). hrms, m/z 301.9820 found (calculated for $C_{14}H_9NO_2{}^{79}Br$, C^+ requires 301.9817).

3-Bromo-1-(2-oxo-4a,8a-dihydro-2*H*-chromen-3-yl)pyridinium bromide (**5j**). The compound (**5j**) was prepared from 2-(bromoacetoxy)benzaldehyde (**3b**) (1 g, 4.11 mmoles) and 3-bromo pyridine (0.65 g, 4.11 mmoles) according to the experimental procedure used for (**5b**) after a reaction time of 12 hours under reflux. This compound was obtained as yellow needles, mp > 260°C and 69% yield. ^{1}H nmr (D_2O): δ 7.47 (t, 2H, J = 8.7 Hz, H-6', H-8'), 7.79 (t, 2H, J = 7.7 Hz , H-5', H-7'), 8.13 (t, 1H, J = 7.9 Hz, H-5), 8.59 (s, 1H, H-4'), 8.90 (d, 1H, J = 8.4 Hz, H-4), 9.03 (d, 1H, J = 6 Hz, H-6), 9.33 (s, 1H, H-2). ^{13}C nmr (D_2O): δ 116.91 (C-8'), 117.27 (C-3'), 123.04 (C-4a'), 126.29 (C-6'), 128.74 (C-3), 129.08 (C-5'), 130.46 (C-7'), 135.47 (C-5), 142.89 (C-4), 144.28 (C-6), 146.48 (C- 2), 150.95 (C-4'), 153.53 (C-8a'), 157.99 (CO). hrms, m/z 301.9815 found (calculated for $C_{14}H_9NO_2{}^{79}Br$, C^+ requires 301.9817).

Typical Procedure for the Preparation of Compounds 6(a-o) from Chloride or Bromide Salts 5(a-j) by Anionic Metathesis. A mixture of 3.28 mmoles of chloride or bromide salt (**5**) and ammonium tetrafluoroborate (0.34 g, 3.28 mmoles) or potassium hexafluorophosphate (0.60 g, 3.28 mmoles) or sodium dicyanamide (0.29 g, 3.28 mmoles) dissolved in 50 ml

of dry acetonitrile was stirred vigorously at 70°C under a stream of nitrogen for 24 hours. After cooling down to room temperature, the precipitated salt (ammonium chloride, or potassium chloride, or sodium chloride) was eliminated by filtration on a filter paper. The resulting filtrate was quickly re-filtered through a pad of Celite® to remove some residual salt and finally concentrated by rotary evaporation that gave the expected salt (**6**). The compound (**6**) was further dried under high vacuum (10-2 Torr) at 60°C for 2 hours. The compound (**6**) was stored in the dark under an inert atmosphere.

1-Methyl-3-(2-oxo-4a,8a-dihydro-2*H*-chromen-3-yl)imidazolium tetrafluoroborate (**6a**). Yield 89%. Beige needles, mp 224-226°C. ^{1}H nmr ($(D_3C)_2SO$): δ 4.01 (s, 3H, Me), 7.57 (td, 2H, J = 7.5 Hz, H-6', H-8'), 7.77 (t, 1H, J = 7.8 Hz, H-7'), 7.83 (d, 1H, J = 7.7 Hz, H-5'), 7.91 (s, 1H, H-4), 8.12 (s, 1H, H-5), 8.63 (s, 1H, H-4'), 9.64 (s, 1H, H-2). ^{13}C nmr ($(D_3C)_2SO$): δ 36.22 (q, J = 144 Hz), 116.39 (dd, J = 168, 8 Hz, C-8'), 117.58 (m, C-3'), 121.62 (d, J = 4 Hz, C-4a'), 122.46 (ddd, J = 207, 13.5 Hz, C-4), 123.66 (dm, J = 199 Hz, C-5), 125.59 (dd, J = 160, 8 Hz, C-5'), 129.44 (dm, J = 165 Hz, C-6'), 133.55 (dm, J = 162 Hz, C-7'), 137.28 (dm, J = 222 Hz, C-2), 137.41 (dd, J = 170, 5 Hz, C-4'), 152.43 (m, C-8a'), 156.18 (d, J = 8 Hz, CO). hrms, m/z 227.0821 found (calculated for $C_{13}H_{11}N_2O_2$, C^+ requires 227.0821).

1-Methyl-3-(2-oxo-4a,8a-dihydro-2*H*-chromen-3-yl)imidazolium hexafluorophosphate (**6b**). Yield 92%. White needles, mp > 260°C. ^{1}H nmr ($(D_3C)_2SO$): δ 4.01 (s, 3H, Me), 7.51 (t, 1H, J = 7.4 Hz, H-8'), 7.59 (d, 1H, J = 8.3 Hz, H-6'), 7.78 (t, 1H, J = 7.6 Hz, H-7'), 7.85 (d, 1H, J = 7.6 Hz, H-5'), 7.93 (s, 1H, H-4), 8.12 (s, 1H, H-5), 8.64 (s, 1H, H-4'), 9.63 (s, 1H, H-2). ^{13}C nmr ($(D_3C)_2SO$): δ 36.24 (q, J = 144 Hz), 116.43 (dd, J = 167, 8 Hz, C-8'), 117.62 (m, C-3'), 121.72 (d, J = 4 Hz, C-4a'), 122.50 (ddd, J = 207, 12, 4 Hz, C-4), 123.71(dm, J = 205 Hz, C-5), 125.6 (dd, J = 166, 8 Hz, C-5'), 129.47 (dm, J = 162 Hz, C-6'), 133.56 (dm, J = 163 Hz, C-7'), 137.28 (dm, J = 222 Hz, C-2), 137.44(dd, J = 169, 5 Hz, C-4'), 152.43 (m, C-8a'), 156.19 (d, J = 8 Hz, CO). hrms, m/z 599.1294 found (calculated for $C_{26}H_{22}N_4O_4F_6P$, $[2C^+, PF_6^-]^+$ requires 599.1284).

1-Methyl-3-(2-oxo-4a,8a-dihydro-2*H*-chromen-3-yl)imidazolium dicyanamide (**6c**). Yield 98%. Beige needles, mp 171-173°C. ^{1}H nmr ($(D_3C)_2SO$): δ 4.02 (s, 3H, Me), 7.48 (td, 1H, J = 8.2, 0.6 Hz, H-8'), 7.58 (d, 1H, J = 8.3 Hz, H-6'), 7.77 (td, 1H, J = 7.2, 1.5 Hz, H-7'), 7.85 (dd, 1H, J = 7.7, 1.3 Hz, H-5'), 7.96 (t, J = 1.6 Hz, 1H, H-4), 8.14 (t, J = 1.8 Hz, H-5), 8.68 (s, 1H, H-4'), 9.67 (s, 1H, H-2). ^{13}C nmr ($(D_3C)_2SO$): δ 36.29 (q, J = 144 Hz), 116.43 (dd, J = 167, 7 Hz, C-8'), 117.58 (m, C-3'), 121.68 (dd, J = 205, 4 Hz, C-4a'), 122.49 (ddd, J = 203, 13, 5 Hz, C-4), 123.73(dm, J = 202 Hz, C-5), 125.60 (dd, J = 165, 8 Hz, C-5'), 129.46 (dm, J = 162 Hz, C-6'), 133.54 (dm, J = 167 Hz, C-7'), 137.25 (dd, J = 170, 5 Hz, C-4'), 137.45 (dm, J = 222 Hz, C-2), 152.44 (m, C-8a'), 156.17 (d, J = 8 Hz, CO). hrms, m/z 520.1735 (calculated for $C_{28}H_{22}N_7O_4$, $[2C^+, N(CN)_2^-]^+$ requires 520.1733).

1-(2-Oxo-4a,8a-dihydro-2*H*-chromen-3-yl)pyridinium tetrafluoroborate (**6d**). Yield 96%. Beige needles, mp > 260°C. ^{1}H nmr ($(D_3C)_2SO$): δ 7.54 (t, 1H, J = 7.5 Hz, H-8'), 7.65 (d, 1H, J = 8.3 Hz, H-6'), 7.84 (td, 1H, J = 8.6, 1.3 Hz, H-7'), 7.89 (d, 1H, J = 7.8 Hz, H-5'), 8.37 (t, 2H, J = 7.4 Hz, H-3, H-5), 8.77 (s, 1H, H-4'), 8.85 (t, 1H, J = 7.9 Hz, H-4), 9.23 (d, 2H, J = 5.6 Hz, H-2, H-6). ^{13}C nmr ($(D_3C)_2SO$): δ 115.60 (dd, J = 168, 8 Hz, C-8'), 116.53 (m, C-3'), 124.76 (d, J = 9 Hz, C-6'); 126.95 (m, C-4a'), 128.01 (m, C-5'), 129.11 (m, C-3, C-5), 133.37 (ddd, J = 164, 8, 2 Hz, C-7'), 139.71 (dd, J = 171, 5 Hz, C-2, C-6), 144.83 (dm, J = 182 Hz, C-4), 147.26 (t, J = 6 Hz, C-4'), 152.16 (m, C-8a'), 155.44 (d, J = 8 Hz, CO). hrms m/z 224.0714 found (calculated for $C_{14}H_{10}NO_2$, C^+ requires 224,0712).

1-(2-Oxo-4a,8a-dihydro-2*H*-chromen-3-yl)pyridinium hexafluorophosphate (**6e**). Yield 97%. White needles, mp > 260°C. ^{1}H nmr ($(D_3C)_2SO$): δ 7.56 (t, 1H, J = 7.5 Hz, H-8'), 7.67 (d, 1H, J = 8.3 Hz, H-6'), 7.86 (td, 1H, J = 7.3, 1.1 Hz, H-7'), 7.91 (d, 1H, J = 7.7 Hz, H-5'), 8.41 (t, 2H, J = 7.1 Hz, H-3, H-5), 8.82 (s, 1H, H-4'), 8.88 (t, 1H, J = 7.9 Hz, H-4), 9.27 (d, 2H, J = 6 Hz, H-2, H-6). ^{13}C nmr ($(D_3C)_2SO$): δ 115.56 (dd, J = 166, 8 Hz, C-8'), 116.48 (m, C-3'), 124.69 (d, J = 9 Hz, C-6'), 126.90 (t, J = 6 Hz, C-4a'), 127.94(m, C-5'), 129.04 (m, C-3, C-5), 133.29 (ddd, J = 164, 8, 2 Hz, C-7'), 139.64 (dd, J = 171, 5 Hz, C-2, C-6), 144.81 (dm, J = 178 Hz, C-4), 147.21 (t, J = 6 Hz, C-4'), 152.10 (m, C-8a'), 155.37 (d, J = 8 Hz, CO). hrms, m/z 224.0714 found (calculated for $C_{14}H_{10}NO_2$, C^+ requires 224,0712).

1-(2-Oxo-4a,8a-dihydro-2*H*-chromen-3-yl)pyridinium dicyanamide (6f). Yield 89%. Brownish needles, mp 219-221°C. ^{1}H nmr ($(D_3C)_2SO$): δ 7.54 (t, 1H, J = 7.5 Hz, H-8'), 7.65 (d, 1H, J = 8.3 Hz, H-6'), 7.85 (td, 1H, J = 7.6, 1.3 Hz, H-7'), 7.91 (d, 1H, J = 7.5 Hz, H-5'), 8.41 (t, 2H, J = 7.1 Hz, H-3, H-5), 8.86 (s, 1H, H-4'), 8.88 (t, 1H, J = 6.9 Hz, H-4), 9.29 (d, 2H, J = 5.8 Hz, H-2, H-6). ^{13}C nmr ($(D_3C)_2SO$): δ 117.14 (dd, J = 168, 8 Hz, C-8'), 118.07 (m, C-3'), 126.25 (d, J = 9 Hz, C-6'), 128.50 (m, C-4a'), 129.45 (m, C-5'), 130.64 (m, C-3, C-5), 134.86 (ddd, J = 164, 8, 2 Hz, C-7'), 141.25 (dd, J = 171, 5 Hz, C-2, C-6), 146.39 (dm, J = 182 Hz, C-4), 148,80 (t, J = 6 Hz, C-4'), 153.66 (m, C-8a'), 156.95 (d, J = 8 Hz, CO). hrms, m/z 514.1524 (calculated for $C_{30}H_{20}N_5O_4$, $[2C^+, N(CN)_2^-]^+$ requires 514,1515).

4-Dimethylamino-1-(2-oxo-4a,8a-dihydro-2*H*-chromen-3-yl)pyridinium tetrafluoroborate (**6g**). Yield 98%. White needles, mp 250-252°C. ^{1}H nmr ($(D_3C)_2SO$): δ 3.30 (s, 6H, Me), 7.22 (d, 2H, J = 7 Hz, H-3, H-5), 7.51 (t, 1H, J = 7.3 Hz, H-8'), 7.60 (d, 1H, J = 8.4 Hz, H-6'), 7.78 (t, 1H, J = 7.8 Hz, H-7'), 7.84 (d, 1H, J = 7.5 Hz, H-5'), 8.38 (d, 2H, J = 7.2 Hz, H-2, H-6), 8.56 (s, 1H, H-4'). ^{13}C nmr ($(D_3C)_2SO$): δ 40.62 (C-8, C-9), 107.82 (C-8'), 116.9 (C-6'), 118.55 (C-5'), 125.97 (C-3'), 128.60 (C-7'), 130.03 (C-4a'), 133.89 (C-3, C-5), 139.24 (C-2, C-6), 142.49 (C-4'), 153.25 (C-4), 156.82 (C-8a'), 157.64 (CO). hrms, m/z 267.1134 (calculated for $C_{16}H_{15}N_2O_2$, C^+ requires 267.1136).

4-Dimethylamino-1-(2-oxo-4a,8a-dihydro-2*H*-chromen-3-yl)pyridinium hexafluorophosphate (**6h**). Yield 96%. White needles, mp > 260°C. ^{1}H nmr ($(D_3C)_2SO$): δ 3.30 (s, 6H, Me), 7.23 (d, 2H, J = 7.8 Hz, H-3, H-5), 7.50 (t, 1H, J = 7.5 Hz, H-8'), 7.59 (d, 1H, J = 8.4 Hz, H-6'), 7.77 (t, 1H, J = 7.5 Hz, H-7'), 7.84 (d, 1H, J = 7.20 Hz, H-5'), 8.39 (d, 2H, J = 7.8 Hz, H-2, H-6), 8.58 (s, 1H, H-4'). ^{13}C nmr ($(D_3C)_2SO$): δ 40.62 (C-8, C-9), 107.81 (C-8'), 116.90 (C-6'), 118.55 (C-5'), 125.95 (C-3'), 128.58 (C-7'), 130.02 (C-4a'), 133.87 (C-3, C-5), 139.24 (C-2, C-6), 142.50 (C-4'), 153.24 (C-4), 156.82 (C-8a'), 157.64 (CO). hrms, m/z 679.1920 found (calculated for $C_{32}H_{30}N_4O_4F_6P$, $[2C^+, PF_6^-]^+$ requires 679.1909).

4-Dimethylamino-1-(2-oxo-4a,8a-dihydro-2*H*-chromen-3-yl)pyridinium dicyanamide (**6i**). Yield 95%. White needles, mp 210-212°C. ^{1}H nmr ($(D_3C)_2SO$): δ 3.29 (s, 6H, Me), 7.23 (d, 2H, J = 7.5 Hz, H-3, H-5), 7.49 (t, 1H, J = 7.5 Hz, H-8'), 7.57 (d, 1H, J = 8.4 Hz, H-6'), 7.76 (t, 1H, J = 7.8 Hz, H-7'), 7.84 (d, 1H, J = 7.5 Hz, H-5'), 8.39 (d, 2H, J = 7.2 Hz, H-2, H-6), 8.61 (s, 1H, H-4'). ^{13}C nmr ($(D_3C)_2SO$): δ 40.69 (C-8, C-9), 107.86 (C-8'), 116.88 (C-6'), 118.53 (C-5'), 125.93 (C-3'), 128.49 (C-7'), 130.03 (C-4a'), 133.86 (C-3, C-5), 139.24 (C-2, C-6), 142.47 (C-4'), 153.22 (C-4), 156.80 (C-8a'), 157.62 (CO). hrms, m/z

600.2350 found (calculated for $C_{34}H_{30}N_7O_4$, [$2C^+$, $N(CN)_2^-$]+ requires 600.2359).

3-Chloro-1-(2-oxo-4a,8a-dihydro-2*H*-chromen-3-yl)pyridinium tetrafluoroborate (**6j**). Yield 98%. Yellow needles, mp 220-222°C. ^{1}H nmr ($(D_3C)_2SO$): δ 7.56 (t, 1H, J = 7.5 Hz, H-8'), 7.67 (d, 1H, J = 8.3 Hz, H-6'), 7.89 (t, 1H, J = 7.4 Hz, H-7'), 7.93 (d, 1H, J = 7.7 Hz, H-5'), 8.43 (t, 1H, J = 8,4 Hz, H-5), 8.80 (s, 1H, H-4'), 9.02 (d, 1H, J = 8.5 Hz, H-4); 9.27 (d, 1H, J = 6.1 Hz, H-6), 9.64 (s, 1H, H-2). ^{13}C nmr ($(D_3C)_2SO$): δ 117.19 (C-8'), 117.83 (C-3'), 126.41 (C-6'), 128.80 (C-4a'), 129.13 (C-5'), 130.81 (C-7'), 134.55 (C-5), 135.17 (C-3); 141.75 (C- 4), 145.34 (C- 6), 145.65 (C- 2), 148.35 (C- 4'), 153.68 (C-8a'), 156.51 (CO). hrms, m/z 258.0328 found (calculated for $C_{14}H_9NO_2{}^{35}Cl$, C^+ requires 258.0322).

3-Chloro-1-(2-oxo-4a,8a-dihydro-2*H*-chromen-3-yl)pyridinium hexafluorophosphate (**6k**). Yield 97%. Beige needles, mp 240-243°C. ^{1}H nmr ($(D_3C)_2SO$): δ 7.56 (t, 1H, J = 7.4 Hz, H-8'), 7.67 (d, 1H, J = 8.3 Hz, H-6'), 7.87 (t, 1H, J = 7.5 Hz, H-7'), 7.94 (d, 1H, J = 7.5 Hz, H-5'), 8.45 (t, 1H, J = 7.1 Hz, H-5), 8.88 (s, 1H, H-4'), 9.05 (d, 1H, J = 8.2 Hz, H-4); 9.31 (d, 1H, J = 5.6 Hz, H-6), 9.69 (s, 1H, H-2). ^{13}C nmr ($(D_3C)_2SO$): δ 117.20 (C-8'), 117.84 (C-3'), 126.39 (C-6'), 128.74 (C-4a'), 129.15 (C-5'), 130.82 (C-7'), 134.51 (C-5); 135.16 (C-3), 141.78 (C-4), 145.35 (C-6), 145.65 (C-2), 148.34 (C- 4'), 153.67 (C-8a'), 156.62 (CO). hrms, m/z 258.0324 found (calculated for $C_{14}H_9NO_2{}^{35}Cl$, C+ requires 258.0322).

3-Chloro-1-(2-oxo-4a,8a-dihydro-2*H*-chromen-3-yl)pyridinium dicyanamide (**6l**). Yield 99%. Beige needles, mp 210-212°C. ^{1}H nmr ($(D_3C)_2SO$): δ 7.53 (t, 1H, J = 7.2 Hz, H-8'), 7.66 (d, 1H, J = 8 Hz, H-6'), 7.86 (t, 1H, J = 7.5 Hz, H-7'), 7.93 (d, 1H, J = 7.1 Hz, H-5'), 8.45 (t, 1H, J = 7.8 Hz, H-5), 8.83 (s, 1H, H-4'), 9.04 (d, 1H, J = 7.9 Hz, H-4), 9.30 (d, 1H, J = 5.1 Hz, H-6), 9.69 (s, 1H, H-2). ^{13}C nmr ($(D_3C)_2SO$): δ 117.19 (C-8'), 117.83 (C-3'), 126.38 (C-6'), 128.73 (C-4a'), 129.15 (C-5'), 130.82 (C-7'), 134.50 (C-5), 135.15 (C-3), 141,78 (C-4), 145.34 (C-6), 145.65 (C-2), 148.33 (C- 4'), 153.67 (C-8a'), 156.61 (CO). hrms, m/z 582.0728 found (calculated for $C_{30}H_{18}N_5O_4{}^{35}Cl_2$, [$2C^+$, $N(CN)_2^-$]$^+$ requires 582.0736).

3-Bromo-1-(2-oxo-4a,8a-dihydro-2*H*-chromen-3-yl)pyridinium tetrafluoroborate (**6m**). Yield 99%. Orange needles, mp 224-226°C. ^{1}H nmr ($(D_3C)_2SO$): δ 7.56 (t, 1H, J = 7.5 Hz, H-8'), 7.67 (d, 1H, J = 8.3 Hz, H-6'), 7.87 (t, 1H, J = 7.8 Hz, H-7'), 7.93 (d, 1H, J = 7.7 Hz, H-5'), 8.35 (t, 1H, J = 7.2 Hz, H-5), 8.80 (s, 1H, H-4'), 9.13 (d, 1H, J = 8.2 Hz, H-4); 9.29 (d, 1H, J = 5.8 Hz, H-6), 9.68 (s, 1H, H-2). ^{13}C nmr ($(D_3C)_2SO$): δ 117.20 (C-8'), 117.86 (C-3'), 122.37 (C-4a'), 126.39 (C-6'), 128.77(C-3), 129.15 (C-5'), 130.80 (C-7'), 135.14 (C-5), 141.73 (C-4), 145.48 (C-6), 147.40 (C-2), 151.03 (C- 4'), 153.67 (C-8a'), 156.66 (CO). hrms, m/z 301.9815 found (calculated for pour $C_{14}H_9NO_2{}^{79}Br$, C^+ requires 301.9817).

3-Bromo-1-(2-oxo-4a,8a-dihydro-2*H*-chromen-3-yl)pyridinium hexafluorophosphate (**6n**). Yield 98%. Yellowish needles, mp > 260°C. ^{1}H nmr ($(D_3C)_2SO$): δ 7.53 (t, 1H, J = 7.1 Hz, H-8'), 7.67 (d, 1H, J = 7.9 Hz, H-6'), 7.86 (t, 1H, J = 7.2 Hz ; H-7'), 7.93 (d, 1H, J = 7.2 Hz, H-5'), 8.36 (t, 1H, J = 7 Hz, H-5), 8.83 (s, 1H, H-4'), 9.13 (d, 1H, J = 7.9 Hz, H-4), 9.31 (d, 1H, J = 4.9 Hz, H-6), 9.69 (s, 1H, H-2). ^{13}C nmr ($(D_3C)_2SO$): δ 117.19 (C-8'), 117.86 (C-3'), 122.38 (C-4a'), 126.38 (C-6'), 128.74 (C-3), 129.15 (C-5'), 130.79 (C-7'), 135.12 (C-5), 141.74 (C-4), 145.47 (C-6), 147.4 0 (C- 2), 151.01 (C- 4), 153.67 (C-8a'), 156.67 (CO). hrms, m/z 748.9270 found (calculated for $C_{28}H_{18}N_2O_4F_6{}^{79}Br_2P$, [$2C^+$, PF_6^-]$^+$ requires 748.9275).

3-Bromo-1-(2-oxo-4a,8a-dihydro-2*H*-chromen-3-yl)pyridinium dicyanamide (**6o**). Yield 99%. Orange needles, mp 220-222°C. ^{1}H nmr ($(D_3C)_2SO$): δ 7.55 (t, 1H, J = 7.3 Hz, H-8'), 7.65 (d, 1H, J = 8.3 Hz, H-6'), 7.86 (t, 1H, J = 7.7 Hz, H-7'), 7.93 (d, 1H, J = 7.5 Hz, H-5'), 8.37 (t, 1H, J = 7.1 Hz, H-5), 8.88 (s, 1H, H-4'), 9.14 (d, 1H, J = 8.2 Hz, H-4); 9.33 (d, 1H, J = 5.7 Hz, H-6), 9.71 (s, 1H, H-2). ^{13}C nmr ($(D_3C)_2SO$): δ 117.19 (C-8'), 117.87 (C-3'), 122.40 (C-4a'), 126.36 (C-6'), 128.70 (C-3), 129.18 (C-5'), 130.80 (C-7'), 135.11 (C-5), 141.75 (C-4), 145.48 (C-6), 147.37 (C- 2), 151.01 (C-4'), 153.66 (C-8a'), 156.66 (CO). hrms, m/z 669.9727 found (calculated for $C_{30}H_{18}N_5O_4{}^{79}Br_2$, [$2C^+$, $N(CN)_2^-$]$^+$ requires 669.9726).

Acknowlegement. We are grateful to the "Accord programme de Coopération Mixte Inter Universitaire Algéro-Français N° 03 MDU 574" for financial assistance (K.B)".

REFERENCES AND NOTES

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[1] R. D. H. Murray, J. Mendez and S. A. Brown, in The Natural Coumarins, Wiley, New York, 1982.

[2] Kirk- Othmer, Encyclopaedia of Chemical Technology, 3rd ed., Vol. **7**, Wiley, New York, 1997, pp 196-906.

[3a] R. S. Mali, S. N. Yeola and B. K. Kulkarni, *Indian J. Chem, Sect. B*, **22**, 352 (1983); [B] P. Loew, Ciba-Geigy A. G., German Patent 271 0285 (1976); *Chem. Abstr.*, **87**, 186 083 (1977).

[4a] R. Rane, H. Harnish and K. H. Drexhage, *Heterocycles*, **21**, 167 (1984); [b] M. Zimmerman, E. Yurewiez and G. Patel, *Anal. Biochem.*, **70**, 258 (1976).

[5] M. Maeda, Laser Dyes, Academic Press, New York, 1984.

[6] P. Laurin, M. Klirch, C. Dupis-Hamelin, P. Mauvais, P. Lassaigne, A. Bonnefoy and B. Musicki, *Bioorg. Med. Chem. Lett.*, **9**, 2079 (1999).

[7] G. Roma, M. D. Braccio, A. Carrieri, G. Grossi, G. Leoncini, M. Grazia-Signorello and A. Carotti, *Bioorg. Med. Chem. Lett.*, **11**, 123 (2003).

[8] S. Kirkiacharian, D. T. Thuy, S. Siesic, R. Bakhchinian, R. Kurkjian and T. Tonnaire, *Farmaco*, **57**, 703 (2002).

[9a] S. P. Pillai, S. R. Menon, L. A. Mitscher, C. A. Pillai, and D. A. Shankel, *J. Nat. Prod.*, **62**, 1358 (1999); [b] S. Kawaii, Y. Tomono, K. Ogawa, M. Sugiura, M. Yano and Y. Yoshizawa, *Anticancer Res.*, **21**, 917, (2001).

[10a] E. R. Bissel, A. R. Mitchell and R. E. Smith, *J. Org. Chem.*, **45**, 2283 (1980); [b] J. P. G. Versleijen, A. M. van Lausen and B. L. Feringa, *Tetrahedron Lett.*, **40**, 5083 (1999).

[11a] B. J. Donnelly, D. M. Donnelly and A. M. D. Sullivan, *Tetrahedron*, **24**, 2617 (1968); [b] J. R. Merchant and A. S. Gupta, *Indian J. Chem, Sect. B*, **17**, 178 (1979).

[12] I. Yavari, R. Heckmat-Shoar and A. Zanouzi, *Tetrahedron Lett.*, **39**, 2391 (1998).

[13a] F. Bigi, L. Chesini, R. Maggi and G. Sartoni, *J. Org. Chem.*, **64**, 1033 (1999); [b] F. Fringuelli, O. Piermatti and F. Pizzo, *Synthesis*, 2331 (2003); [c] J. R. Harjini, S. J. Nara and M. M. Salunkhe, *Tetrahedron Lett.*, **43**, 1127 (2002).

[14] S. Palaniappan and R. C. Shekhar, *J. Mol. Cat. A: Chem.*, **209**, 117 (2004).

[15a] V. Singh, S. Kaur, V. Sapehiya, J. Singh and G. L. Kad, *Cat. Commun.*, **6**, 57 (2005); [b] E. V. O. John and S. S. Israelstom, *J. Org. Chem.*, **26**, 240 (1961); [c] D. G. Crosby, *J. Org. Chem.*, **26**, 215 (1961).

[16] D. V. Kadnikov and R. C. Larock, *J. Org. Chem.*, **68**, 9423 (2003).

[17] M. Rehwald, P. Bellmann, T. Jeschke and K. Gewald, *J. Prakt. Chem.*, **342**, 371 (2000).

[18] P. S. Salunkhe, C. P. Phadke, S. L. Kelkar and M. S. Wadia,

Synthesis, 111 (1985).

[19] L. Bonsignore, F. Cottiglia, H. Elkhaili, F. Jehl, S. M. Lavagna, G. Loy, F. Manna, H. Monteil, D. Pompei and D. Secci, *Farmaco*, **53**, 425 (1998).

[20] L. Bonsignore, A. De Logu, G. Loy, S. M. Lavagna and D. Secci, *Eur. J. Med. Chem.*, **29**, 479 (1994).

[21] M. Glosbeek and H. Zhang, *Chem. Rev.*, **104**, 1929 (2004).

[22] J. C. Legeay, J. J. Vanden Eynde and J. P. Bazureau, *Tetrahedron*, **61**, 12386 (2005).

[23] R. C. Fuson and N. Thomas, *J. Org. Chem.*, **18**, 1762 (1953).

[24] A. I. A. Vogel, in Textbook of Quantitative Inorganic Analysis, 3rd ed., Longmans, Green and Co: London, 1961.

[25] A. Arfan and J. P. Bazureau, *Org. Process Res. Dev.*, **9**, 743 (2005).