Pyrylium-mediated Transformations of Natural Products. Part 3.[1] Synthesis of Water-soluble Pyrylium Salts and their Preparative Reactions with Amines

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A series of water-soluble pyrylium salts and zwitterions has been prepared containing two or three carboxylic or sulphonic acid groups. These pyrylium salts react in aqueous solution with ammonia to give the corresponding pyridines and with n-butylamine, benzylamine, and the ω-amino groups of lysine to give the corresponding pyridinium systems, usually as betaines. The pyridinium betaines (m.p. > 300 °C) show characteristic ^{13}C n.m.r. spectra which have been nearly fully assigned.

Pyridinium salts (1b) derived from primary amines and 2,4,6-triphenylpyrylium ion (1a) undergo nucleophilic displacements of the *N*-substituent under rather severe conditions.[2] Pyridinium salts of types (2b) and (3b) are more reactive than (1b) and react with N, S, O, P, and halide nucleophiles at 30—80 °C.[3,4] Triphenylpyridinium salts (1b) also undergo radical reactions with nitronate anions and several other carbon nucleophiles at 25—100 °C leading to *C*-alkylation of the anion by the *N*-substituent.[5,6]

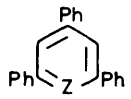
Following our demonstration that pyrylium ions rendered water-soluble by sulphonic acid groups[7] would react with amines in aqueous solution to give pyridinium salts,[1] we have turned our attention to further water-soluble pyrylium salts, including some that possess the more reactive leaving groups of type (2b). We report here the synthesis of the water-soluble pyrylium salts (4a)—(8a). These possess structural and electronic characteristics similar to those of the arylpyrylium salts known to be active in the transformation of amines into other functionalities.[2-4] We have studied the reactions of (4a)—(8a) with amines in aqueous solution to give the corresponding pyridinium salts.

The strategy used to solubilize these arylpyrylium salts has been to attach hydrophilic sulphonic and carboxylic acid groups to the aryl substituents. The successful sulphonation of 1,5-diphenyl-3-(2-thienyl)pentane-1,5-dione and its conversion into the corresponding pyrylium salt (9) has been reported,[8] but (9) is not sufficiently water-soluble. 1,5-Bis-(*p*-methoxyphenyl)-3-carboxypentane-1,5-dione (10a) has been sulphonated,[9] but the purification of the product is difficult. Problems were expected in the direct sulphonation of arylpyrylium salts; therefore it was planned to construct the pyrylium ring from appropriately functionalized components.

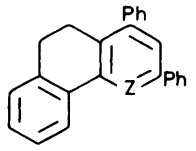
An alternative approach to solubilize pyrylium salts by attachment of polyhydroxylated residues was also tried. Attempts to prepare polyhydroxylated esters of 2,6-diphenyl-4-carboxypyrylium failed[9,10] when the corresponding acid chloride could not be prepared. Although water-soluble esters of 2-thienylacetic acid were obtained[11] *via* transesterification of the methyl ester with tetraethylene glycol, the same reaction failed when applied to 2,6-diphenyl-4-ethoxycarbonylpyrylium.[9]

Preparation of Pyrylium Salts (*Table* 1).—Three approaches have been used, depending on the type of product: (a) for the symmetrical triaryl systems (4a) and (5a) 2 mol equiv. of the corresponding functionalized acetophenone (11a) or (11b) were condensed with benzaldehyde in the presence of perchloric acid [Scheme 1(a)].

4-Phenyl-2,6-bis-(4-carboxyphenyl)pyrylium perchlorate (4a) (34%) was prepared by direct condensation of benzalde-



(1)



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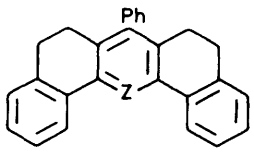
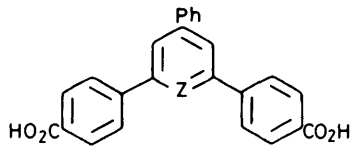


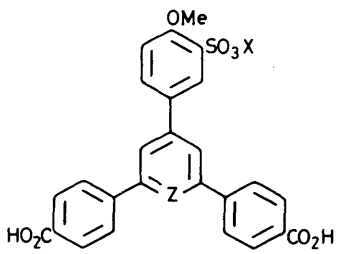
(3)

a; Z = O^+
b; Z = N^+R



(4)

a; Z = O^+ ClO_4^-
b; Z = N
d; Z = N^+Bu^n ClO_4^-
e; Z = N^+CH_2Ph ClO_4^-



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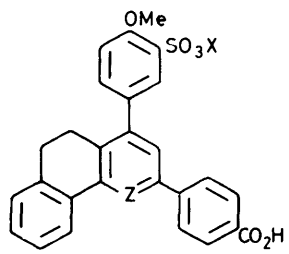
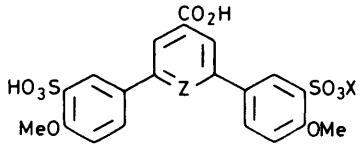


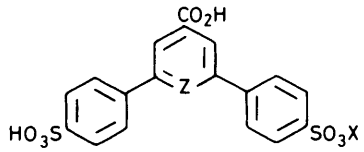
(6)

a; Z = O^+ ClO_4^-, X = H
b; Z = N, X = Na
c; Z = N^+-CH_3, X = negative charge
d; Z = N^+-Bu^n, X = negative charge
e; Z = N^+-CH_2Ph, X = negative charge
f; Z = $N^+[CH_2]_4CH(NH_2)CO_2H$, X = negative charge



(7)

a; Z = O^+, X = negative charge
b; Z = N^+H ClO_4^-, X = H
d; Z = N^+Bu^n, X = negative charge
f; Z = $\overset{+}{N}[CH_2]_4CH(\overset{+}{N}H_3)CO_2H$ ClO_4^-, X = negative charge



(8)

a; Z = O^+, X = negative charge
b; Z = $\overset{+}{N}H$ ClO_4^-, X = H
d; Z = $\overset{+}{N}Bu^n$ ClO_4^-, X = H
f; Z = $\overset{+}{N}[CH_2]_4CH(\overset{+}{N}H_3)CO_2H$ ClO_4^-, X = negative charge
g; Z = $\overset{+}{N}CH_2CH_2Ph$ ClO_4^-, X = H

hyde with *p*-acetylbenzoic acid, the high m.p. of which required the use of acetic anhydride as solvent. In acetic acid, the intermediate chalcone (12) precipitated, hindering further pyrylium formation.

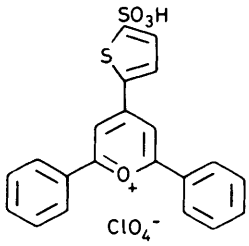
The condensation of *p*-acetylbenzoic acid with *m*-sulpho-*p*-methoxybenzaldehyde (14a) in acetic anhydride in the presence of perchloric acid yielded 2,6-bis-(4-carboxyphenyl)-4-(4-methoxy-3-sulphophenyl)pyrylium perchlorate (5a) (36%).

For the unsymmetrical system (6a), Scheme 1(b) was followed; the intermediate chalcone was treated with 1 mol equiv. of the acetophenone. 2-(4-Carboxyphenyl)-4-(4-methoxy-3-sulphophenyl)-5,6-dihydrobenzo[*h*]chromenylium perchlorate (6a) (60%) was prepared by this method from the chalcone (13) and *p*-acetylbenzoic acid in perchloric acid.

2,6-Diaryl-4-carboxypyrylium betaines (7a) and (8a) were prepared [Scheme 1(c)] by cyclisation and oxidation of the intermediate 1,5-diketones (10b and c) with trityl tetrafluoroborate [12] (Table 1).

3-Carboxy-1,5-bis-(4-methoxy-3-sulphophenyl)pentane-1,5-dione (10b) was obtained from sodium 5-acetyl-2-methoxybenzenesulphonate and glyoxylic acid with sodium hydroxide. Similarly sodium *p*-acetylbenzenesulphonate gave 3-carboxy-1,5-bis-(4-sulphophenyl)pentane-1,5-dione (10c).

Sodium 5-acetyl-2-methoxybenzenesulphonate [13] (11c), *p*-acetylbenzoic acid [14] (11a), and sodium 5-formyl-2-methoxybenzenesulphonate [7] (14b) were all prepared by literature methods [for (11c) a modified procedure was used; see Experimental section]. The chalcone (13) was obtained by reaction of sodium 5-formyl-2-methoxybenzenesulphonate (14b) and α-tetralone with sodium hydroxide. The pyrylium synthesis intermediates (10b), (10c), and (13) have not been reported previously. They were characterized spectroscopically (^1H and ^{13}C n.m.r.) but in general could not be obtained pure enough for elemental analysis.



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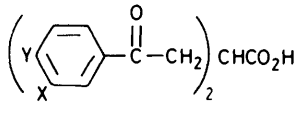
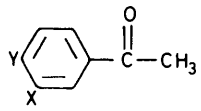


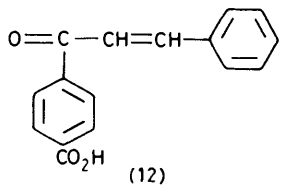
(10)

a; Y = OMe, X = H
b; Y = OMe, X = SO_3H
c; Y = SO_3H, X = H



(11)

a; Y = CO_2H, X = H
b; Y = SO_3H, X = H
c; Y = OMe, X = SO_3Na



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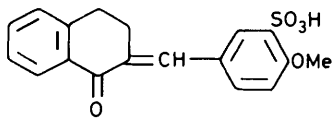

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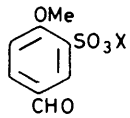
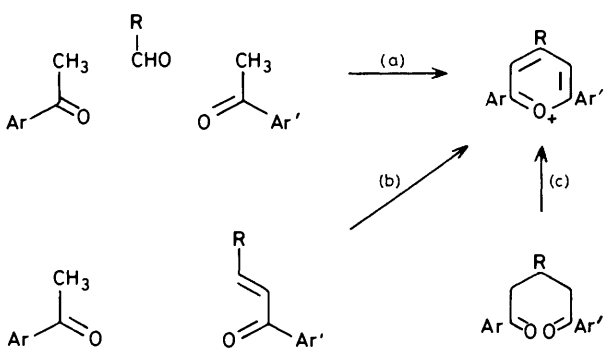


(14)

a; X = H
b; X = Na

All the pyrylium salts (4a)—(8a) are water-soluble. In aqueous solution all are in equilibrium with the corresponding enedione pseudobases [*i.e.* (15) and (16)] and pseudobase anions [*i.e.* (17) and (18)], the respective concentrations depending on the pH of the solution (see refs. 7 and 15 for kinetic studies of these equilibria).

Preparation of Pyridines and Pyridinium Salts.—The new pyrylium salts (4a)—(8a) were treated in water with ammonia and amines such as methylamine, n-butylamine, and benzylamine. Two main methods were used. (*a*) The finely powdered solid pyrylium salt was added gradually to the amine dissolved



Scheme 1.

Table 1. Preparation of pyridines and *N*-substituted pyridinium salts

Cpd. no.	*N*-Substituent	Anion	Recryst. solvent	Crystal form	M.p. (°C)	Pr. [a]	Yield (%)	Found (Required) (%) C	H	N	S	Molecular formula
(4b)			EtOH (95%)	Off-white prisms	>330	B	81	75.7 (75.9	4.4 4.3	3.5 3.5)		$C_{25}H_{17}NO_4$
(4d)	Bu^n	ClO_4^-	EtOH–H_2O	Pale yellow prisms	>330	B	75	62.1 (62.1	4.9 4.8)			$C_{29}H_{26}ClNO_8$
(4e)	$PhCH_2$	ClO_4^-	EtOH–H_2O	Pale yellow prisms	>330	B	71	69.5 (69.5	4.3 4.5)			$C_{64}H_{46}ClN_2O_{12}\cdot 2H_2O$ [b]
(5b)			EtOH	White prisms	>320	A	73	57.3 (57.2	3.8 3.7)			$C_{26}H_{18}NaNO_8S\cdot H_2O$
(5c)	Me	*c*	CH_3OH	White prisms	>330	A	74	60.7 (60.3	4.1 4.3)			$C_{27}H_{21}NO_8S\cdot H_2O$
(5d)	Bu^n	*c*	EtOH	White prisms	>330	B A	58 53	62.5 (62.2	4.8 5.0)			$C_{30}H_{27}NO_8S\cdot H_2O$
(5e)	$PhCH_2$	*c*	EtOH [e]	Pale yellow prisms	>330	B A	72 52	64.4 (64.6	4.2 4.4)			$C_{33}H_{25}NO_8S\cdot H_2O$
(5f)	$HO_2CCH(\overset{+}{N}H_3)[CH_2]_4$	*c*	H_2O	Pale yellow prisms	>330	A	36	55.4 (55.8	4.8 5.2)			$C_{32}H_{30}N_2O_{10}S\cdot 3H_2O$
(6b)			EtOH–H_2O [e]	White prisms	>330	C	75	57.2 (57.1	4.1 4.1	2.5 2.5)		$C_{27}H_{19}Na_2NO_6S\cdot 2H_2O$
(6c)	CH_3	*c*	EtOH	Grey-white prisms	>330	B	70	64.7 (64.7	4.9 4.8	2.7 2.7)		$C_{28}H_{23}NO_6S\cdot H_2O$
(6d)	Bu^n	*c*	EtOH	Pale yellow prisms	>330	B	54	66.2 (66.3	5.6 5.5	2.5 2.5	5.6 5.7)	$C_{31}H_{29}NO_6S\cdot H_2O$
(6e)	$PhCH_2$	*c*	EtOH–H_2O	Yellow prisms	>330	B	72	68.5 (68.6	4.9 4.9	2.3 2.3	5.3 5.0)	$C_{34}H_{27}NO_6S\cdot H_2O$
(6f)	$HO_2CCH(\overset{+}{N}H_3)[CH_2]_4$	*d*	EtOH	Yellow prisms	>300	D	33	52.4 (52.6	5.0 4.9	3.6 3.7	4.2 4.3)	$C_{33}H_{33}ClN_2O_{12}S\cdot 2H_2O$
(7b)		ClO_4^-	CH_3OH	Off-white prisms	>300	E	76	40.3 (40.3	3.1 3.0		10.7 10.8)	$C_{20}H_{18}ClNO_{14}S_2$
(7d)	Bu^n	*c*	EtOH (95%)	Pale yellow prisms	>300	E	74	*f*				
(7f)	$HO_2CCH(\overset{+}{N}H_3)[CH_2]_4$	*d*	EtOH (95%)	Pale yellow prisms	>300	F	42	41.5 (41.5	4.2 4.3	3.5 3.7	8.3 8.5)	$C_{26}H_{29}ClN_2O_{16}S_2\cdot 1.5H_2O$
(8b)		ClO_4^-	EtOH (95%)	Off-white prisms	>300	E	60	40.2 (40.3	2.6 2.6	2.4 2.6)		$C_{18}H_{14}ClNO_{12}S_2$
(8d)	Bu^n	ClO_4^-	EtOH (95%)	Pale yellow prisms	>300	E	62	40.9 (40.9	4.4 4.4	2.1 2.2	9.9 9.9)	$C_{22}H_{22}ClNO_{12}S_2\cdot 3H_2O$
(8f)	$HO_2CCH(\overset{+}{N}H_3)[CH_2]_4$	*d*	EtOH (95%)	Pale yellow prisms	>300	F	38	41.7 (41.7	3.9 4.1	4.0 4.1)		$C_{24}H_{25}ClN_2O_{14}S_2\cdot 1.5H_2O$
(8g)	$PhCH_2CH_2$	ClO_4^-	EtOH (95%)	Pale yellow prisms	>300	E	71	48.7 (48.8	3.5 3.5	2.2 2.2	10.0 10.0)	$C_{26}H_{22}ClNO_{12}S_2$

[a] Pr = Procedure (see Experimental section). [b] Hemiperchlorate, dihydrate. [c] Betaine forms. [d] Zwitterionic perchlorates. [e] Triturated at boiling temperature. [f] Satisfactory analysis not obtained owing to hygroscopic nature of compound.

in water at pH 9; in this case the pyrylium salt itself reacts with the amine as kinetic work has shown.[1] (*b*) Separate solutions of the pyrylium salt and the amine in water at pH *ca.* 9—10 were mixed. Here the pyrylium salt had already been converted into the enedione pseudobase; it is this that reacts with the amine, and the reaction is slower. Acidification with perchloric acid frequently precipitated the pyridine or the pyridinium salt. When precipitation did not occur after acidification, acetone was added. Sodium perchlorate is soluble in acetone, and the pyridines and pyridinium salts were not contaminated with inorganic salts. (After acidification with hydrochloric acid, the products could not be isolated pure.) As shown by analysis, the form in which the pyridines are isolated depends on the pH at precipitation: as sodium sulphonates at pH 2—3 [(5b) and (6b)], and as pyridinium perchlorates at pH < 1 [(7b) and (8b)]. Pyridinium ions were obtained as betaines except (4d), (8d), and (8g), which separated as perchlorates, and (4e) which separated as a hemiperchlorate. The results (Table 1) were similar to those obtained [1-3] with non-water-soluble pyrylium salts (1a) and (2a) in organic solvents, and the corresponding pyridines and pyridinium salts were obtained in yields varying from 81 to 36% (average 64%).

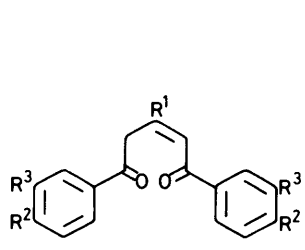
Pyrylium salts (5a), (6a), (7a), and (8a) were also treated with the amino acid lysine, giving the corresponding pyridinium salts (5f), (6f), (7f), and (8f) derived from reaction at the ω-amino group (see Table 1). The *N*-[amino(carboxy)-pentyl]-4-carboxypyridinium salts are very water-soluble and were isolated (yields 30—40%) at pH < 1 as perchlorates by addition of acetone.

^1H *N.m.r. Spectra.*—^1H N.m.r. shifts of pyrylium salts, pyridines, and pyridinium salts are given in Tables 2—4. Assignments reflect the perturbations introduced in (1a), (1b), (2a), and (2b) when sulpho, carboxy, and methoxy groups are substituted into the pendant phenyl rings. Regarding the pyridinium salts (Table 4), the α-aryl groups are observed to have the following effects on the *N*-substituent protons (as compared with the corresponding amine hydrochlorides): (*a*) deshielding of the protons at the carbon atom directly adjacent

Table 2. ^{1}H Chemical shifts of pyrylium salts (δ)

Cpd. no.	Heterocycle 3-, 5-H	Free α-aryl rings 2′-H	3′-H	5′-H	6′-H	γ-Aryl rings 2′-H	5′-H	6′-H	Fixed α-aryl rings 2′-H	3′-H	4′-H	5′-H	OMe	CH_2CH_2
(4a) [a]	8.37 [d]	8.05 [d]	8.05 [d]	8.05 [d]	8.05 [d]	7.50–7.80 [e]		7.10–7.40 [f]						
(5a) [a]	8.33 [d]	8.03 [d]	8.03 [d]	8.03 [d]	8.03 [d]	8.30 [d]	7.00 [g]	7.70–8.00 [h]					3.60 [d]	
(6a) [a]	8.10–8.30 [h]	8.07 [d]	8.07 [g]	8.07 [d]	8.07 [d]	*h*	6.10–7.90 [i]	7.40–7.60 [h]		6.90–7.90 [j]			3.63 [d]	2.50–2.90 [k]
(7a) [b]	8.38 [d]	8.28 [l]		7.20 [g]	8.08 [m]								3.97 [d]	
(8a) [c]	8.70 [d]	8.17 [g]	7.83 [g]	7.83 [g]	8.17 [g]									

[a] In CF_3SO_3H, ref. TSP $[(CH_3)_3SiCD_2CD_2CO_2^-Na^+]$. [b] In D_2O, ref. DSS $[(CH_3)_3SiCD_2CD_2CD_2SO_3^-Na^+]$. [c] In CF_3SO_3H, ref. to Me_4Si. [d] Singlet. [e] Multiplet, 2 H, for 2′-, 6′-H. [f] Multiplet, 3 H, for 3′-, 4′-, 5′-H. [g] Doublet, *J* 8.5 Hz. [h] Concealed. [i] Not clear. [j] Multiplet, 4 H, for 2′-, 3′-, 4′-, 5′-H. [k] Multiplet. [l] Doublet, *J* 2.0 Hz. [m] Doublet of doublets, J_1 8.5, J_2 2.0 Hz.



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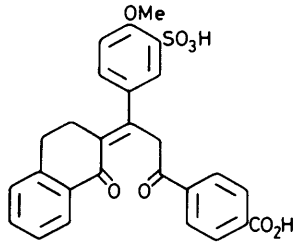

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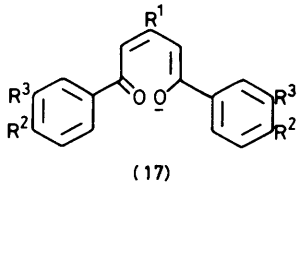

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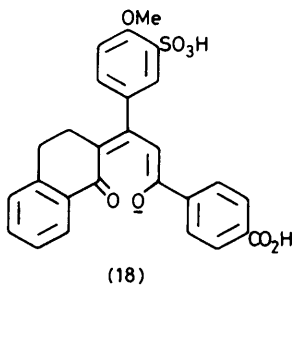
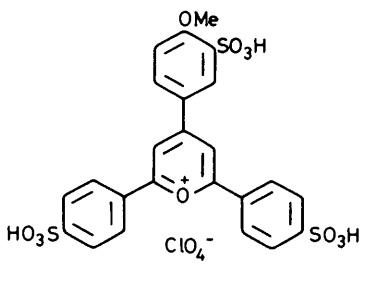


(18)



(19)

to the pyridinium nitrogen; (*b*) shielding of the protons at carbons β, γ, and δ to the pyridinium nitrogen (*e.g.* n-butyl and lysine pyridinium salts); and (*c*) shielding of the aryl protons of *N*-benzylpyridinium salts (4e) and (5e). These effects arise from the non-coplanarity of the α-aryl substituents with the pyridinium ring as described for the 2,4,6-triphenylpyridinium salt [16] (1b).

^{13}C *N.m.r. Spectra.*—^{13}C N.m.r. chemical shifts of the pyrylium salts, pyridines, and pyridinium salts prepared are given in Tables 5—10. Assignments follow chemical shift considerations,[17] data from off-resonance decoupled spectra, and comparison with previous assignments for related compounds.[7,18] Signals from alkyl substituents were assigned readily from observed shifts and off-resonance spectra.

Assignments for pyrylium ring carbon atoms are given in Table 5. The α (169.7—169.8), β (116.4—118.4), and γ (164.8—166.3 p.p.m.) carbon shifts of (4a) and (5a) are very close to those reported [18] for (1a), (C_α, 170.0; C_β, 115.1; C_γ, 165.1 p.p.m.). The same applies for (6a) (C-2, 170.5; C-3, 119.5; C-4, 166.2; C-5, 126.0; C-6, 165.5 p.p.m.) *versus* the reported [18] (2a) (C-2, 167.8; C-3, 119.3; C-4, 167.0; C-5, 126.3; C-6, 166.4 p.p.m.). Substitution in the aryl substituents thus has little effect on the pyrylium carbon chemical shifts, which are dominated by the charge density change, with respect to benzene, due to the heterocyclic oxygen.[19]

Replacement of the 4-aryl group in (19) [7] by a carboxy group (8a) produces higher field absorptions for α and γ carbon atoms [164.2 and 157.3 p.p.m. in (8a) *versus* 169.0 and 164.6 p.p.m. in (19)] whilst the β-carbon absorption is shifted downfield [122.2 in (8a), 114.6 p.p.m. in (19)]. The 4-carboxy group causes an effect larger in magnitude and opposite in sign in the pyrylium ring as compared with benzene.[17] Although a definitive conclusion is precluded by the use of different solvents [D_2O for (19) and CF_3SO_3H for (8a)], it is known [18-20] that a more acidic solvent increases the chemical shifts (absorptions shifted downfield) of pyrylium carbon atoms; therefore, the observed reduction of chemical shift for α and γ carbon atoms in our case (8a) (CF_3SO_3H as solvent), should be significant. No other ^{13}C data for 4-carboxypyrylium salts have been described.

Pyridinium and pyridine ring carbon atoms (*Table* 7). Good agreement is found between the chemical shifts of α (155.3—157.5), β (125.3—127.2), and γ (153.7—156.3 p.p.m.) carbon atoms in the 2,4,6-triarylpyridinium series [(4d), (4e), (5c), (5d), (5e), (5f), (6c), (6d), (6e), (6f)] and the corresponding α (156.0—158.5), β (126.0—127.9), and γ (154.0—158.0 p.p.m.) carbon atoms in (1b) and (2b) reported.[18]

Pyridines [(4b), (5b), (6b)] have the α-carbon absorption virtually unaffected (157.1—157.3 p.p.m.). The β and γ carbon atoms of pyridines have higher field absorptions (C_β, 111.6—118.0; C_γ, 149.8—153.9 p.p.m.) than the corresponding pyridinium salts, as previously reported.[18,19] Trends in the γ-carboxypyridinium salts [(7d), (7f), (8d), (8f)] and pyridiniums [(7b) and (8b)] are similar to those observed in the γ-carboxypyrylium salts, the absorption due to γ carbon appearing at higher field than the corresponding absorption in 2,4,6-triaryl-pyridinium salts and -pyridines.

Aryl substituents. As in the 2,4,6-triphenyl series [18] conjugation with the strongly electron-deficient pyrylium ring deshields the 4′-carbon atom of the α- or γ-aryl substituent far

Table 3. ^{1}H Chemical shifts (δ) of pyridines and pyridinium salts (except *N*-substituents)

Cpd. no.	*N*-Substituent	Hetero-cycle	Free α-aryl rings		γ-Aryl rings				Fixed α-aryl rings			
		3-, 5-H	2′-, 6′-H	3′-, 5′-H	2′-H	3′-H	4′-H	5′-H	6′-H	2′-, 4′-H	3′-, 5′-H	OMe	CH_2CH_2
(4b) [a]		6.70—7.20 [c]	7.87 [e]	7.37 [e]		6.70		7.20 [f]					
(4d) [a]	Bu^n	7.83 [d]	8.24 [e]	7.80 [e]		7.20		7.80 [f]					
(4e) [a]	$PhCH_2$	7.78 [d]	8.05 [e]	7.48 [e]		7.20		7.70 [f]					
(5b) [b]		7.20 [d]	7.87 [g]	7.58 [e]	8.06 [d]			6.53 [e]	7.00—7.25 [g]			3.75 [d]	
(5c) [b]	Me	7.96 [d]	8.17 [e]	7.82 [e]	8.26 [d]			7.23 [e]	7.60—7.90 [g]			3.92 [d]	
(5d) [b]	Bu^n	7.95 [d]	8.15 [e]	7.80 [e]	8.25 [d]			7.23 [e]	*c*			3.96 [d]	
(5e) [b]	$PhCH_2$	8.08 [d]	8.15 [e]	7.60 [e]	8.45 [d]			7.10—7.30 [g]	*c*			4.13 [d]	
(5f) [b]	$HO_2CCH(\overset{+}{N}H_3)[CH_2]_4$	8.00 [d]	8.17 [g]	7.82 [e]	8.27 [d]			7.10—7.40 [f]	*c*			3.97 [d]	
(6b) [b]		7.20 [d]	7.96 [e]	7.90 [e]	8.10 [g]			6.60—6.90 [c]	7.75 [g]	7.10 [g]	6.56 [g]	3.86 [d]	1.90—2.20 [f]
(6c) [b]	Me	7.75 [d]	8.06 [e]	7.86 [g]	8.20 [d]			7.20—7.40 [c]	7.60—7.90 [g]	7.43 [f]	7.20 [f]	4.06 [d]	2.60 [d]
(6d) [b]	Bu^n	7.90—8.00 [c]	8.25 [e]	8.06 [g]	8.38 [d]			7.20—7.60 [g]	7.60—7.80 [g]	7.30—7.80 [f]		4.10 [d]	2.50—3.00 [f]
(6e) [b]	$PhCH_2$	*c*	8.00 [e]	7.83 [e]	8.10 [d]			*c*	*c*	7.10—7.70 [f]		4.15 [d]	1.90—3.00 [f]
(6f) [b]	$HO_2CCH(\overset{+}{N}H_3)[CH_2]_4$	*c*	8.16 [e]	7.87 [e]	7.90 [d]			6.90—7.20 [f]	7.30—7.60 [c]	7.10—7.70 [f]		3.92 [d]	2.30—2.80 [f]
(7b) [a]		7.90 [d]	8.42 [h] 7.90 [i]	7.10 [e]								4.06 [d]	
(7d) [a]	Bu^n	8.20 [d]	8.23 [h] 7.96 [i]	7.48 [e]								4.12 [d]	
(7f) [a]	$HO_2CCH(NH_3)[CH_2]_4$	8.32 [d]	8.12 [h] 7.95 [i]	7.41 [e]								4.07 [d]	
(8b) [a]		7.75 [d]	8.03 [j]	7.84 [j]									
(8d) [a]	Bu^n	8.42 [d]	8.22 [e]	7.95 [e]									
(8f) [a,l]	$HO_2CCH(\overset{+}{N}H_3)[CH_2]_4$	8.30 [d]	8.08 [j]	7.80 [j]									
(8g) [a]	$PhCH_2CH_2$	8.15 [d]	8.03 [e]	7.62 [e]									

[a] In D_2O, ref. TSP. [b] in D_2O, ref. DSS. [c] Concealed. [d] Singlet. [e] Doublet, *J* 8.5 Hz. [f] Multiplet. [g] Not clear. [h] Doublet, *J* 2.0 Hz. [i] Double doublet, J_1 8.5, J_2 2.0 Hz. [j] Doublet, *J* 9.5 Hz. [l] pH 5; spectrum very pH dependent.

Table 4. ^{1}H Chemical shifts (δ) of pyridinium salt *N*-substituents

Cpd. no.	*N*-Substituent	1′-H	2′-H	3′-H	4′-H	5′-H	Ph
(4d) [a]	Bu^n	4.20—4.60 [c]	1.10—1.60 [d]	0.10—1.00 [c]	0.30 [d]		
(4e) [a]	$PhCH_2$	5.50 [e]					6.20—7.30 [c]
(5c) [b]	Me	3.87 [e]					
(5d) [b]	Bu^n	4.20—4.60 [c]	1.10—1.60 [c]	0.50—1.00 [c]	0.37 [d]		
(5e) [b]	$PhCH_2$	5.62 [e]					6.30—7.30 [c]
(5f) [b]	$HO_2CCH(\overset{+}{N}H_3)[CH_2]_4$	4.10—4.30 [c]	0.50		2.00 [c]	3.30—3.60 [c]	
(6c) [b]	Me	3.90 [e]					
(6d) [b]	Bu^n	5.10—5.35 [c]	0.80—1.50 [c]	0.50—0.80 [c]	0.20—0.50 [c]		
(6e) [b]	$PhCH_2$	6.00 [e]					6.50—7.10 [c]
(6f) [b]	$HO_2CCH(\overset{+}{N}H_3)[CH_2]_4$	4.40—4.70 [c]	0.60		1.40 [c]	3.20—3.50 [c]	
(7d) [a]	Bu^n	4.30—4.70 [c]	1.20—1.70 [c]	0.60—1.10 [c]	0.43 [d]		
(7f) [a]	$HO_2CCH(\overset{+}{N}H_3)[CH_2]_4$	4.30—4.60 [c]	1.00		1.90 [c]	3.80—4.00 [c]	
(8d) [a]	Bu^n	4.30—4.70 [c]	1.20—1.70 [c]	0.60—1.10 [c]	0.40 [d]		
(8f) [a]	$HO_2CCH(\overset{+}{N}H_3)[CH_2]_4$	4.20—4.60 [c]	0.90		1.80 [c]	4.00—4.10 [c]	
(8g) [a]	$PhCH_2CH_2$	6.20—6.50 [c]	2.40—2.70 [c]				7.15 [c]

[a] In D_2O, ref. TSP. [b] In D_2O, ref. DSS. [c] Multiplet. [d] Triplet, *J* 5.5 Hz. [e] Singlet.

more than the 1′-, 2′-, or 3′-carbon atom (*cf.* refs. 18 and 19) (Table 6). As the electron deficiency of the heterocycle is reduced (through pyridinium to pyridines) the 1′-carbon atom becomes more strongly deshielded, with the 2′-, 3′-, and 4′-carbon atoms little affected (see Table 8). Substituents in the aryl substituents have similar effects to those in benzene. Experimental values show good agreement with those calculated using 2,4,6-triphenylpyrylium (1a) as the parent and the perturbation values for the benzene series.[17]

The chemical shifts of unsubstituted α-phenyl groups

Table 5. ^{13}C Chemical shifts (δ) [a] of pyrylium ring carbon atoms

Cpd. no.	Substituents R²	R³	R⁴	R⁵	R⁶	^{13}C Chemical shifts C-2	C-3	C-4	C-5	C-6
(4a)	*p*-$HO_2CC_6H_4$	H	C_6H_5	H	*p*-$HO_2CC_6H_4$	169.7	118.4	164.8	118.4	169.7
(5a)	*p*-$HO_2CC_6H_4$	H	*m*-HO_3S-*p*-$MeOC_6H_3$	H	*p*-$HO_2CC_6H_4$	169.8	116.8	166.3	116.8	169.8
(6a)	*p*-$HO_2CC_6H_4$	H	*m*-HO_3S-*p*-$MeOC_6H_3$		C_8H_8	170.5	119.5	166.2	126.0	165.5
(7a)	*m*-HO_3S-*p*-$MeOC_6H_3$	H	CO_2H	H	*m*-HO_3S-*p*-$MeOC_6H_3$	165.9	113.8 [a]	165.6	111.8 [b]	165.9
(8a)	*p*-$HO_3CC_6H_4$	H	CO_2H	H	*p*-$HO_3SC_6H_4$	164.2	122.2	157.3	122.2	164.2

[a] In CF_3SO_3H, ref. $CDCl_3$ (δ 77.0). [b] 113.8 or 111.8 p.p.m.

Table 6. ^{13}C Chemical shifts (δ) [a] of pyrylium substituents

Cpd. no.	Free α-aryl groups C-1′	C-2′	C-3′	C-4′	C-5′	C-6′	γ-Aryl groups C-1′	C-2′	C-3′	C-4′	C-5′	C-6′	α-CO_2H	OMe
(4a)	132.9	129.7	133.8	137.1	133.8	129.7	131.2	130.4	128.5	134.0	128.4	130.4	179.6	
(5a)	133.6	129.6	133.4	137.0	133.4	129.6	126.2	128.4	129.7	164.1	117.6	133.7	179.7	57.7
(6a)	133.6	128.2 [b]	130.6 [b]	137.9	130.6 [b]	128.2 [b]	127.2	127.5 [b]	129.7 [b]	160.8	114.0	131.7	171.6	56.9
(7a)	118.1	129.4	129.3	154.2	*c*	135.4							175.7	48.0
(8a)	133.5	132.1	130.0	148.0	130.0	132.1							176.0	

[a] In CF_3SO_3H, ref. $CDCl_3$ (δ 77.0). [b] Tentative assignments. [c] 113.8 or 111.8 p.p.m.

Table 7. ^{13}C Chemical shifts (δ) [a] of pyridines and pyridinium ring carbon atoms

Cpd. no.	Substituents R¹	R²	R³	R⁴	R⁵	R⁶	^{13}C Chemical shifts C-2	C-3	C-4	C-5	C-6
(4b)		*p*-$HO_2CC_6H_4$	H	C_6H_5	H	*p*-$HO_2CC_6H_4$	157.1	118.0	149.8	118.0	157.1
(4d)	Bu^n						156.7	126.9	155.6	126.9	156.7
(4e)	$PhCH_2$						157.5	127.2	156.3	127.2	157.5
(5b)		*p*-$HO_2CC_6H_4$	H	*m*-SO_3Na-*p*-$MeOC_6H_3$	H	*p*-$HO_2CC_6H_4$	156.5	111.6	147.5	111.6	156.5
(5c)	Me						157.3	125.3	153.9	125.3	157.3
(5d)	Bu^n						156.7	125.6	153.7	125.6	156.7
(5e)	$PhCH_2$						157.4	127.2	154.9	127.2	157.4
(5f)	$HO_2CCH(\overset{+}{N}H_3)[CH_2]_4$						156.6	126.0	154.1	126.0	156.6
(6b)		*p*-$HO_2CC_6H_4$	H	*m*-SO_3Na-*p*-$MeOC_6H_3$	H	C_8H_8	154.3	121.4 [b]	148.4	126.1 [b]	153.0
(6c)	Me						155.3	127.1	154.4	127.7	154.3
(6d)	Bu^n						155.7	126.8	154.7	128.3	154.6
(6e)	$PhCH_2$						155.9	126.6	155.3	127.2	155.1
(6f)	$HO_2CCH(\overset{+}{N}H_3)[CH_2]_4$						157.1	125.5	156.4	128.9	156.1
(7b)		*p*-MeO-*m*-$SO_3^-C_6H_3$	H	CO_2H	H	*p*-MeO-*m*-$SO_3^-C_6H_3$	156.5	118.6	147.2	118.6	156.5
(7d)	Bu^n						157.0	129.8	152.2	129.8	157.0
(7f)	$HO_2CCH(\overset{+}{N}H_3)[CH_2]_4$						157.2	129.7	147.1	129.7	157.2
(8b)		*p*-$SO_3^-C_6H_4$	H	CO_2H	H	*p*-$SO_3^-C_6H_4$	155.6	119.7	142.8	119.7	155.6
(8d)	Bu^n						157.3	127.0	146.7	127.0	157.3
(8f)	$HO_2CCH(\overset{+}{N}H_3)[CH_2]_4$						157.2	127.3	148.3	127.3	157.2

[a] In D_2O ref. dioxane (δ 67.4). [b] Tentative assignments.

(Table 10) are unaffected by substitution on other aryl groups and agree with those for simpler pyrylium and pyridinium salts [18] (2a) and (2b).

N-*Substituents* (*Table* 9). The 1′-carbon shifts of alkyl and benzyl *N*-substituents appear at low field (46.0—62.8 p.p.m.); the carbon atoms further from nitrogen are less deshielded.

Experimental

^1H N.m.r. spectra were recorded with a Varian EM 360L spectrometer and a JEOL FX-100 spectrometer was used for ^{13}C n.m.r. spectra. I.r. spectra were obtained with a Perkin-Elmer 297 spectrophotometer and u.v. spectra with a Pye Unicam 8-200 instrument. Elemental analyses were performed by Atlantic Microlab, Inc., Atlanta, Georgia. M.p.s were obtained with a Reichert hot stage apparatus.

4-Acetylbenzoic acid (11a) was prepared [14] from 4-methylacetophenone; m.p. 207—208.5 °C (lit., 200—201 °C).

Sodium 5-formyl-2-methoxybenzenesulphonate (14) was prepared (78%) from 4-methoxybenzaldehyde according to the literature procedure [7] but using 20% instead of 30% oleum for sulphonation and methanol instead of water for recrystallisation of the product; m.p. > 350 °C, δ [D_2O with sodium 3-trimethylsilylpropane-1-sulphonate (DSS) as reference] 4.03 (3 H, s), 7.20 (1 H, d, *J* 8.5 Hz), 7.93 (1 H, dd, J_1 8.5, J_2 2.0 Hz), 8.26 (1 H, d, *J* 2.0 Hz), and 9.8 (1 H, s).

Sodium 5-(1-Oxotetralin-2-ylidenemethyl)-2-methoxybenzenesulphonate (13).—Aqueous 1.5M-sodium hydroxide (10

Table 8. ^{13}C Chemical shifts (δ) [a] of pyridines and pyridinium salts α and γ substituents

Cpd. no.	Substituent	Free α-aryl groups						γ-Aryl groups						α-CO_2H	γ-CO_2H	Methoxy	Unassigned shifts
		C-1′	C-2′	C-3′	C-4′	C-5′	C-6′	C-1′	C-2′	C-3′	C-4′	C-5′	C-6′				
(4b)		141.2	127.5 [b]	130.1 [b]	137.3	130.1 [b]	127.5 [b]	137.1	*c*	*c*	130.1	*c*	*c*	175.4			127.1, 129.7
(4d)	Bu^n	135.3	129.7 [b]	130.5 [b]	139.8	130.5 [b]	129.7 [b]	133.2	*c*	*c*	133.8	*c*	*c*	174.3			128.9, 130.5
(4e)	$PhCH_2$	135.0	129.6 [b]	130.4 [b]	140.0	130.4 [b]	129.6 [b]	133.1	*c*	*c*	133.5	*c*	*c*	174.1			128.9, 161.7
(5b)		141.0	129.6 [b]	129.9 [b]	136.9	129.9 [b]	129.6 [b]	130.5	*c*	*c*	157.5	113.4	130.9	175.7		56.4	127.3, 128.0
(5c)	Me	135.3	129.9 [b]	130.3 [b]	139.9	130.3 [b]	129.9 [b]	124.6	*c*	*c*	160.4	114.4	133.9	174.8		57.1	130.2, 129.1
(5d)	Bu^n	135.3	129.8 [b]	130.6 [b]	139.8	130.6 [b]	129.8 [b]	124.9	*c*	*c*	160.0	114.1	133.8	174.5		57.2	131.5, 130.6
(5e)	$PhCH_2$	135.2	129.6 [b]	130.3 [b]	139.7	130.3 [b]	129.6 [b]	125.9	*c*	*c*	160.9	114.6	134.2	175.5		57.2	129.1, 132.5, 134.4
(5f)	$HO_2CCH(\overset{+}{N}H_3)[CH_2]_4$	135.2	129.7 [b]	130.4 [b]	139.8	130.4 [b]	129.7 [b]	125.2	*c*	*c*	160.6	114.5	132.5	174.6		57.2	128.9, 134.0
(6b)		141.5	127.5 [b]	130.3 [b]	137.4	130.3 [b]	127.5 [b]	*c*	*c*	*c*	157.1	112.6	*c*	175.7		56.8	134.4, 133.9, 131.4, 129.6, 129.2, 128.3
(6c)	Me	134.7	127.4 [b]	130.0 [b]	140.1	130.0 [b]	127.4 [b]	128.9	*c*	*c*	158.8	113.8	130.5	174.5		56.9	127.1, 129.5, 129.8, 130.4
(6d)	Bu^n	135.6	128.1 [b]	130.1 [b]	140.2	130.1 [b]	128.1 [b]	128.8	*c*	*c*	159.1	114.0	130.9	174.2		57.1	126.8, 129.1, 129.8
(6e)	$PhCH_2$	135.3	127.4 [b]	129.3 [b]	139.3	129.3 [b]	127.4 [b]	128.3	*c*	*c*	159.1	114.2	130.6	174.2		57.2	127.0, 128.5, 129.8, 130.3, 161.6
(6f) [d]	$HO_2CCH(\overset{+}{N}H_3)[CH_2]_4$	137.6	131.2 [b]	132.0 [b]	141.8	132.0 [b]	131.2 [b]	129.8	*c*	*c*	163.1	117.0	132.6	176.5		58.9	128.9, 130.0, 130.4, 130.7
(7b)		131.1	130.9	127.3	158.0	113.7	132.9								161.3	56.9	
(7d)	Bu^n	124.9	129.8	131.8	159.2	114.2	135.0								161.0	57.1	
(7f)	$HO_2CCH(\overset{+}{N}H_3)[CH_2]_4$	124.4	130.3	131.9	159.4	114.4	134.9								166.3	57.1	
(8b)		140.5	127.7	126.6	144.0	126.6	127.7								170.0		
(8c)	Bu^n	135.2	130.4	127.3 [b]	146.4	127.3 [b]	130.4								165.8		
(8f)	$HO_2CCH(\overset{+}{N}H_3)[CH_2]_4$	135.3	130.4	127.3	146.3	127.3	130.4								166.6		

[a] In D_2O, ref. *p*-dioxane (δ 67.4). [b] Tentative. [c] Unassigned. [d] In D_2O, ref. TSP (δ 0.05).

Table 9. ^{13}C Chemical shifts (δ) [a] of pyridinium *N*-substituents

Cpd. no.	Substituent	^{13}C Chemical shift C-1′	C-2′	C-3′	C-4′	C-5′	C-6′
(4d)	Bu^n	55.4	32.2	19.5	12.8		
(4e)	$PhCH_2$	59.2	134.3	*b*	*b*	126.5	
(5c)	Me	46.0					
(5d)	Bu^n	55.3	32.3	19.4	12.7		
(5e)	$PhCH_2$	59.1	135.2	*b*	*b*	125.1	
(5f)	$HO_2CCH(\overset{+}{N}H_3)[CH_2]_4$	55.1	29.9	22.0	29.9	55.1	174.9
(6c)	Me	50.0					
(6d)	Bu^n	59.9	32.2	18.9	12.9		
(6e)	$PhCH_2$	62.8	134.7	*b*	*b*	126.6	
(6f) [c]	$HO_2CCH(\overset{+}{N}H_3)[CH_2]_4$	56.9	32.3	23.5	32.3	56.9	177.2
(7d)	Bu^n	56.0	32.0	19.5	12.8		
(7f)	$HO_2CCH(\overset{+}{N}H_3)[CH_2]_4$	57.2	29.3	22.0	29.3	53.1	172.3
(8d)	Bu^n	56.6	32.1	19.5	12.6		
(8f)	$HO_2CCH(\overset{+}{N}H_3)[CH_2]_4$	58.3	29.5	21.8	29.2	53.1	172.3

[a] D_2O, ref. dioxane (δ 67.4). [b] Unassigned; see Table 8. [c] In D_2O, ref. TSP (δ 0.05).

Table 10. ^{13}C Chemical shifts (δ) [a] of fixed α-aryl group and ethylene bridge in 2-(4-carboxyphenyl)-4-(4-methoxy-3-sulphophenyl)-5,6-dihydrobenzo[*h*]chromenylium ion (6a) and derivatives

Cpd. no.	Fixed α-aryl groups C-1′	C-2′	C-3′	C-4′	C-5′	C-6′	Ethylene bridge C-5	C-6
(6a) [b]	129.4			136.8		143.0	26.3	25.3
(6b)	138.9	*c*	*c*	*c*	*c*	157.1	27.8	25.4
(6c)	137.9	143.1	*c*	131.9	*c*	158.8	28.0	27.8
(6d)	138.6	142.5	*c*	132.1	*c*	159.1	28.3	27.9
(6e)	138.3	142.4	*c*	132.0	*c*	159.3	28.8	27.7
(6f) [d]	140.9	144.7	*c*	133.5	*c*	160.8	31.9	30.2

[a] In D_2O, ref. dioxane (δ 67.4). [b] In CF_3SO_3H and CF_3CO_2H (1 : 2), ref. $CDCl_3$ (δ 77.0): unassigned peaks at 125.5, 127.2, and 131.1. [c] Unassigned; see Table 8. [d] In D_2O, ref. TSP (δ 0.05).

ml) was added to α-tetralone (2.19 g, 15 mmol) and sodium 5-formyl-2-methoxybenzenesulphonate (3.57 g, 15 mmol) in water (35 ml). The mixture was stirred at 60 °C for 10 h and then kept 12 h at 0 °C. The precipitated *sodium salt* was washed with water and acetone. It crystallised from water (yield 73%) as needles, m.p. > 350 °C (Found: C, 56.4; H, 4.4. $C_{18}H_{15}NaO_5 \cdot H_2O$ requires, C, 56.3; H, 4.4%); δ (CF_3CO_2H with DSS as reference) 2.8—3.2 (4 H, m), 4.03 (3 H, s), and 7.1—8.3 (8 H, m).

2,6-*Bis*-(4-*carboxyphenyl*)-4-*phenylpyrylium Perchlorate* (4a).—Perchloric acid (70%; 2.1 g, 15 mmol) was added dropwise to 4-acetylbenzoic acid (11a) (3.28 g, 20 mmol) and benzaldehyde (1.07 g, 10 mmol) in acetic anhydride (20 ml) with stirring. The mixture was kept at 100 °C for 1 h. The yellow precipitated *perchlorate* was washed with acetic acid and ether and purified by boiling in acetic acid (10 ml) to yield the product as yellow prisms (1.69 g, 34%), m.p. > 350 °C (decomp.) (Found: C, 60.2; H, 3.4. $C_{25}H_{17}ClO_9$ requires C, 60.4; H, 3.4%).

2,6-*Bis*-(4-*carboxyphenyl*)-4-(4-*methoxy*-3-*sulphophenyl*)-*pyrylium Perchlorate* (5a).—Perchloric acid (70%; 14.0 g, 0.1 mol) was added dropwise to 4-acetylbenzoic acid (11a) (8.2 g, 0.05 mol) and sodium 5-formyl-2-methoxybenzenesulphonate (14) (6.0 g, 0.025 mol) in acetic anhydride (40 ml) with stirring. The mixture was kept at 90—100 °C for 1 h. The precipitated *perchlorate* was washed with acetic acid and ether and purified by boiling in acetic acid (60 ml) to yield the product as yellow prisms (5.76 g, 38%), m.p. > 350 °C (decomp.) (Found: C, 51.4; H, 3.2. $C_{26}H_{19}ClO_3S$ requires C, 51.4; H, 3.1%).

2-(4-*Carboxyphenyl*-5,6-*dihydro*-4-(4-*methoxy*-3-*sulphophenyl*)*benzo*[h]*chromenylium Perchlorate* (6a).—Perchloric acid (70%; 7.3 g, 0.052 mol) was added dropwise to the chalcone (13) (11.0 g, 0.03 mol) and 4-acetylbenzoic acid (2.46 g, 0.015 mol) in acetic anhydride (30 ml) with stirring. The temperature was kept at 60—80 °C for 2 h. The precipitated *perchlorate* was washed with acetic anhydride (15 ml), acetic acid (15 ml), and ether (40 ml) to yield the product as brown prisms (5.62 g, 60%), m.p. > 330 °C (decomp.) (Found: C, 51.8; H, 3.9. $C_{27}H_{21}ClO_{11}S.2H_2O$ requires C, 51.9; H, 4.0%).

Sodium 5-*Acetyl*-2-*methoxybenzenesulphonate* (11c) (cf. *ref.* 13).—*p*-Methoxyacetophenone (135 g) was added gradually (1 h) to 30% fuming sulphuric acid (540 g) at 5 °C with efficient stirring. The stirring was continued at 25 °C for 30 min. The mixture was then poured into five times its volume of ice-cold salt solution (525 g NaCl in 1 750 ml water). The precipitate was washed with cold ethanol (25 ml) and recrystallised from ethanol to give the *sodium sulphonate* (91 g, 40%), m.p. > 300 °C; $\nu_{max.}$ ($CHBr_3$) 1 690 (carbonyl), 1 395, 1 360, and 1 200 cm^{-1}; δ (D_2O, referenced to TSP) 8.37 (1 H, d, J^m 2 Hz), 8.04 and 7.90 (1 H, dd, J^o 9, J^m 2 Hz), 7.13 (1 H, d, J^o 9 Hz), 4.08 (3 H, s, OCH_3), and 2.57 (3 H, s, CH_3).

3-Carboxy-1,5-bis-(4-methoxy-3-sulphophenyl)pentane-1,5-dione (10b).—Sodium 5-acetyl-2-methoxybenzenesulphonate (11c) (20.5 g, 81.3 mmol), sodium hydroxide (3.25 g, 81.3 mmol), glyoxylic acid monohydrate (3.01 g, 40.6 mmol), and water (42 ml) were stirred at 25 °C for 24 h. After filtration, the water was removed at 50 °C and 30 mmHg and the residue dissolved in hot methanol. The trisodium salt of (10b) crystallised on cooling (white prisms) and more was obtained from the mother liquor by addition of ethanol (total yield 22.7 g, 96%); $\nu_{max.}$ ($CHBr_3$) 3 595—3 240 (OH), 1 660 (ketone), 1 630 (carboxylate), 1 592, 1 550, 1 490, 1 400, 1 360, 1 300, 1 260, 1 222, 1 200, 1 090, 1 025, 1 000, 825, 710, and 690 cm^{-1}; δ (D_2O, referenced to DSS), 8.4 (2 H, d, J^m 2 Hz), 8.17 and 8.02 (2 H, dd, J^o 9 Hz, J^m 2 Hz), 7.19 (2 H, d, J^o 9 Hz), 4.04 (6 H, s, OCH_3), 3.98—3.78 (1 H, m, methine), and 3.37 (no integral due to H/D exchange, d, J 4 Hz, CH_2).

The trisodium salt (22 g) in water (32 ml) was chromatographed on a cation-exchange resin (220 g; Mallinckrodt Amberlite IR-120, 20—50 mesh) by elution with water (580 ml) until the washings were no longer strongly acidic. The water was removed at 25 °C and 4 mmHg and the exchange procedure repeated to give 3-carboxy-1,5-bis-(4-methoxy-3-sulphophenyl)pentane-1,5-dione (10b) as amber-red, hydroscopic, brittle needles (17.41 g, 89.3%); δ_H (D_2O, referenced to DSS) 8.54 (2 H, d), 8.26 and 8.10 (2 H, dd), 7.24 (2 H, d), 4.10 (6 H, s, OCH_3), 3.96 (1 H, m, methine), and 3.60 (no integral due to H/D exchange, d, CH_2). δ_C (D_2O, referenced to *p*-dioxane, 67.4 p.p.m.) 199.7 (C=O), 179.0 (CO_2H), 161.5 (aryl, C-4), 148.9 (unassigned), 134.4 (aryl, C-6), 131.0 (aryl, C-1), 128.8 (aryl, C-3), 113.3 (aryl, C-5), 57.2 (OCH_3), 40.3 (CH_2), and 35.0 (methine).

3-Carboxy-1,5-bis-(4-sulphophenyl)pentane-1,5-dione (10c).—Sodium *p*-acetylbenzenesulphonate (13.06 g, 58.8 mmol; Aldrich), sodium hydroxide (2.35 g, 58.8 mmol), glyoxylic acid monohydrate (2.18 g, 29.4 mmol), and water (125 ml) were stirred at 25 °C for 24 h; the mixture was then filtered and water removed at 50 °C and 30 mmHg. The tan-coloured trisodium salt was converted immediately into the free acid (10c) *via* cation-exchange chromatography as described for (10b) in an overall yield of 76%; $\nu_{max.}$ ($CHBr_3$) 3 660—3 200, 1 680, 1 590, 1 580, 1 570, 1 425, 1 390, 1 230, 1 180, 1 035, 1 005, 987, and 825 cm^{-1}; δ_H (D_2O referenced to DSS) 8.20—7.6 (8 H, m, arom.), 3.96—3.77 (1 H, m, methine), and 3.77—3.33 (no integral due to H/D exchange, m, CH_2); δ_C (D_2O referenced to *p*-dioxane at 67.4 p.p.m.) 196.1 (C=O), 178.9 (CO_2H), 148.0 (aryl, C-4), 138.7 (aryl, C-1), 129.5 (aryl, C-2), 126.8 (aryl, C-3), 40.8 (CH_2), and 36.9 (methine).

4-Carboxy-2-(4-methoxy-3-sulphonatophenyl)-6-(4-methoxy-3-sulphophenyl)pyrylium (7a) *and 4-Carboxy-2-(4-sulphonatophenyl)-6-(4-sulphophenyl)pyrylium* (8a): *General Method.*—Freshly prepared trityl tetrafluoroborate [12] (27.1 g, 85.2 mmol, 5% excess) was added at 45 °C to the sulphonated diketone (10c) (35.68 g, 78.2 mmol) in acetic acid (144 ml) and acetic anhydride (20 ml). The mixture was refluxed for 20 min (yellow precipitate), and cooled to 15 °C. The product was filtered off under nitrogen, washed with cold, dry ether (3 × 25 ml), and refluxed successively with two portions of acetic acid (75 and 50 ml) for 24 h each. Filtration under nitrogen, washing with cold, dry ether and drying (25 °C and 4 mmHg) yielded the *pyrylium betaine* (8a) as anhydrous yellow prisms (17.63 g, 51%), m.p. > 300 °C (Found: C, 49.3; H, 3.0; S, 14.6. $C_{18}H_{12}O_9S_2$ requires C, 49.5; H, 2.8; S, 14.7%); $\nu_{max.}$ ($CHBr_3$) 3 480—3 320 (OH), 1 740—1 700 (carbonyl), 1 630 (pyrylium), 1 600, 1 530, 1 500, 1 440, 1 250—1 230, 1 050, and 830 cm^{-1}; for ^1H and ^{13}C n.m.r. see Tables 2, 5, and 6.

In a similar fashion, the *betaine* (7a) was isolated as a dihydrate (red prisms, 42% yield, m.p. > 300 °C) (Found: C, 45.1; H, 3.4; S, 12.1. $C_{20}H_{16}O_{11}S_2 \cdot 2H_2O$ requires C, 45.1; H, 3.8; S, 12.0%); $\nu_{max.}$ ($CHBr_3$) 3 460—3 340 (OH), 1 725 (carbonyl), 1 625 (pyrylium), 1 350, 1 175, and 1 030 cm^{-1}; for ^1H and ^{13}C n.m.r. see Tables 2, 5, and 6.

Pyridines and N-Substituted Pyridinium Salts (*Table* 1).—The following six general procedures were used.

Method A. The amine (3.0 mmol) was added dropwise to the pyrylium perchlorate (1.5 mmol) and sodium hydrogen carbonate (0.5 g, 6.0 mmol) in water (10 ml) with stirring. Sodium carbonate (0.15—0.4 g, 1.5—4.0 mmol) was added to adjust to pH 9—10. The solution was left at 25 °C for 4 days, and acidified with perchloric acid (10—14 mmol) to pH 2—3. The precipitated pyridinium salt was washed with water and acetone.

Method B. Sodium hydrogen carbonate (0.42 g, 5 mmol) and the amine (4 mmol) were dissolved in water (10 ml) and sodium carbonate (0.2—0.6 g, 2—6 mmol) was added (to pH 10—11). The pyrylium perchlorate (2.0 mmol) was added in portions with stirring during 10—20 min (pH 9—10). The solution was left at 25 °C for 12—48 h, and acidified with perchloric acid (14—20 mmol to pH 2—3). The precipitate was filtered off and washed with water and acetone.

Method C. As Method B except that the precipitate which formed without acidification was filtered off and washed with water and acetone.

Method D. As Method B but the precipitate did not form upon acidification, so the solution was concentrated *in vacuo* to 3—5 ml and then added dropwise to acetone (150 ml). The precipitate was filtered off and washed with acetone.

Method E. The pyrylium salt (2.25 mmol) was added gradually over 6 h to a buffer-amine solution (15 ml; pH 10—10.5), prepared from sodium hydrogencarbonate (9 mmol), sodium carbonate, and the amine (9 mmol) and stirred at 25 °C for 24—48 h (reaction pH 8.5—10). The excess of amine was removed by either evaporation (45 °C and 30 mmHg), or extraction with ether. Water (12 ml) was added to the residue, and the solution was acidified with $HClO_4$ to pH 0.5—1.0 and concentrated to 6 ml at 45 °C and 30 mmHg. Dropwise addition of the residue with stirring to a large excess of acetone (50—100 ml) precipitated the pyridinium salt, which was filtered off under nitrogen and recrystallised from methanol or ethanol.

Method F. Identical with method E except that 4.5 mmol of lysine were used and the excess of lysine perchlorate was removed in recrystallisation.

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