Participation of *o*-Carboxylate Groups in Aromatic Nucleophilic Substitution

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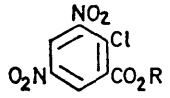
2-Chloro-3,5-dinitrobenzoic acid (1a) reacts with phenols and alcohols in pyridine to give aryl and alkyl 3,5-dinitrosalicylates (2; R = aryl or alkyl), exclusively in most cases, and along with aryl 2-aryloxy-3,5-dinitrobenzoates (5; $R^1 = R^2$ = aryl) in a few cases. Methyl 2-chloro-3,5-dinitrobenzoate (1b) furnishes methyl 2-aryloxy-3,5-dinitrobenzoates (5; R^1 = Me, R^2 = aryl) and aryl salicylates (2; R = aryl). The formation of the aryl salicylates must involve participation of the *o*-carboxy and *o*-alkoxycarbonyl groups. The β-lactone (8) and the ortho-ester (14) are suggested as intermediates to explain the observed acylations.

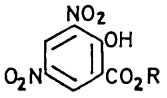
METHYL 2-CHLORO-3,5-DINITROBENZOATE (1b) reacts with certain phenols in the presence of pyridine to give aryl salicylates (2; R = aryl).[1] This unexpected reaction was explained *via* the intermediacy of the lactone (8).

In order to improve our understanding of the mechanism of this reaction, we have investigated the reaction of phenols and alcohols with the parent acid (1a) and with the ester (1b) and we now report our results and conclusions.



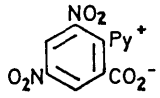
(1)

a, R = H
b, R = Me
c, R = Et
d, R = CH_2Ph



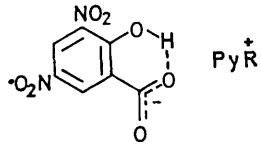
(2)

a; R = Me
b; R = Et
c; R = Pr^n
d; R = Pr^i
e; R = $CH_2{:}CH{\cdot}CH_2$
f; R = Bu^n
g; R = Bu^i
h; R = cyclo-C_6H_{11}
i; R = Menthyl
j; R = *t*-4-Bu^t-1-HC:C-cycloC_6H_9
k; R = Ph
l; R = 2-MeC_6H_4
m; R = 2,4-$Me_2C_6H_3$
n; R = 4-Br-2-MeC_6H_3
o; R = 2,4-Br_2-6-MeC_6H_2
p; R = 2,3,6-Br_3-4-MeC_6H
q; R = 2,4-$Cl_2C_6H_3$
r; R = 4-Br-2-$EtO_2CC_6H_3$
s; R = 2,6-$Me_2C_6H_3$
t; R = 4-BrC_6H_4
u; R = 2-ClC_6H_4
v; R = 2-$MeO_2CC_6H_4$
w; R = 5-Me-2-$Pr^iC_6H_3$
x; R = 2,4-Bu^t_2-6-MeC_6H_2



(3)

Reaction of the Acid (1a) *with Pyridine.*—The crystalline betaine (3) is the major product of the reaction of the acid (1a) with pyridine at room temperature.[2] The minor product (~4%) is identified as the pyridinium 3,5-dinitrosalicylate (4a) from its elemental composition and strong u.v. maximum at 340 nm (ε 12,300). In contrast to the reported [2] failure to hydrolyse the betaine (3) to 3,5-dinitrosalicyclic acid, the salt (4a) was the only isolable product when the acid (1a), its potassium salt, or the betaine (3) was heated with pyridine. Methyl and ethyl 3,5-dinitrosalicylates (2a and b) are formed when the betaine is heated with alcohols in sealed tubes.[2] Further, the alkyl salicylates (2; R = alkyl) are formed when the betaine (3) is heated in *p*-cymene with alcohols, and also when the potassium salt of the acid (1a) is heated in sealed tubes with the alcohols.



(4)

a, R = H
b, R = Me
c, R = 2,4-$(NO_2)_2C_6H_3$
d, R = Et

Reaction of the Acid (1a) *with Phenols and Alcohols.*—The aryl salicylate (2o) was isolated only in small quantities (<5%) when the acid (1a) or its potassium salt was treated in hot pyridine with 2,4-dibromo-6-methylphenol. The major product (~65%) in these experiments was the pyridinium salt (4a). There was no evidence for any additional product (t.l.c.). Under similar conditions, the extent of hydrolysis of the aryl salicylate (2o) was only 15% and the failure to increase the yield of the aryl salicylate (2) is probably due to an effective competition of moisture (either absorbed or present in the pyridine) for the reactive intermediate.

However, improved yields of the aryl and alkyl 3,5-dinitrosalicylates were obtained by using carefully dried pyridine (Table 1). Since the betaine (3) is the initial product of the reaction of the acid (1a) or its potassium salt, and subsequently reacts with water, phenols, or alcohols, most of the reactions were done with the acid (1a) itself. T.l.c. analyses of the reaction mixtures before work-up, revealed mostly the presence of the salicylates (2) and unchanged phenol or the high boiling alcohol used. The products of direct displacements, *viz.*, 2-aryloxy- or 2-alkoxy-3,5-dinitrobenzoic acids were found to be totally absent (t.l.c.). Both alkyl and aryl dinitrosalicylates on t.l.c. show a characteristic yellow spot (R_F 0·5 on 0·25 mm SiO_2, benzene–acetone, 3 : 2) and have strong u.v. maxima at *ca.* 360 nm (log ε 4) and reduced C=O frequencies ($\nu_{C=O}$ 1670—1710 cm^{-1}). For comparison, a few aryl salicylates (2; R = aryl) were prepared from 3,5-dinitrosalicyl chloride.[3]

[1] R. Muthukrishnan, R. Kannan, and S. Swaminathan, *J.C.S. Chem. Comm.*, 1972, 358.

[2] Th. Zincke, *J. prakt. Chem.*, 1910, **82**, 17.

[3] E. Weber, J. Sieben, and R. Anspach, *Annalen*, 1906, **346**, 336.

TABLE 1

Reactions of the chloro-acid (1a) and methyl ester (1b) with phenols and alcohols

Phenol or alcohol	Yields (%) from reaction with acid (1a) Aryl or alkyl salicylate (2)	Salt (4a)	Yields (%) from reaction with ester (1b) Methyl ester (5; R^1 = Me)	Aryl salicylate (2)
PhOH	16·7	5·6	46	*a*
2-MeC_6H_4OH	33·3	*a*, *b*	45·3	*a*
2,4-$Me_2C_6H_3OH$	29·2	14·5 [b]	36·7	*a*, *c*
4-Br-2-MeC_6H_3OH	42·1	*a*, *b*	24·8	6·3 [d]
2,4-Br_2-6-MeC_6H_2OH	52·5	*a*	*a*	85
2,3,6-Br_3-4-MeC_6HOH	44·8	*a*	*a*	49
2,4-$Cl_2C_6H_3OH$	21·1	*a*	*a*	15·4
4-Br-2-$EtO_2CC_6H_3OH$	35·4	*a*	*a*	35·4
2,6-$Me_2C_6H_3OH$	42·6	*a*	35	*a*
4-BrC_6H_4OH	27·5	*a*	13	*a*
2-ClC_6H_4OH	34·9	13·3	*a*	*a*, *c*
2-$MeO_2CC_6H_4OH$	33·3	*a*	*e*	*e*
Thymol	13·2	2·5		
3-MeC_6H_4OH	*e*	*e*	42·3	*a*
4-MeC_6H_4OH	*e*	*e*	46	*a*
2-$MeOC_6H_4OH$	*e*	*e*	42	*a*
4-$Bu^tC_6H_4OH$	*e*	*e*	69·7	*a*
2-Naphthol	*e*	*e*	34	*a*
2,4-Bu^t_2-6-MeC_6H_2OH	*e*		*a*	20
MeOH	9·0	*a*, *f*	*e*	*e*
EtOH	30·9	*a*	*e*	*e*
Pr^nOH	33·4	*a*	*e*	*e*
Pr^iOH	52·7	*a*	*e*	*e*
Bu^nOH	27·7	*a*	*e*	*e*
Bu^iOH	40·2	*a*	*e*	*e*
Cyclo-$C_6H_{11}OH$	48·5	*a*	*e*	*e*
Menthol	47·5	*a*	*e*	*e*
t-4-Bu^t-1-HC:C-cyclo-C_6H_9OH	4·1	32·7	*e*	*e*

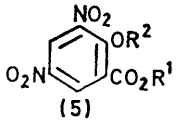
[a] Not isolated. [b] The corresponding aryl esters (5b) (1·7), (5c) (4·1), and (5d) (2·4%) were also isolated. [c] The methylpyridinium salt (4b) was isolated in yields of 11 and 32·6%. [d] Aryl ester (5d) (2·2) and acid (6d) (3·0%) were also isolated. [e] Reaction not done. [f] Reaction period 1·5 h.

Acylations of tertiary alcohols did not occur readily; with *t*-4-t-butyl-1-ethynylcyclohexan-*r*-1-ol, the yield of the alkyl salicylate (2j) is only 4·1%.

Other Products.—From the reactions with *o*-cresol, 2,4-dimethylphenol and 4-bromo-2-methylphenol, small quantities of colourless by-products were isolated. The high i.r. carbonyl frequencies at 1740—1760 cm^{-1} indicate that these are aryl esters. Conversion of 2-aryloxy-3,5-dinitrobenzoic acids (6; R = aryl), *via* their acid chlorides, into the aryl esters (5; $R^1 = R^2$ = aryl), afforded samples identical with those obtained in the reactions of the acid (1a).

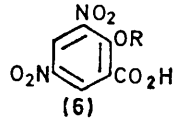
Aryloxy-acids (6; R = Aryl).—Williamson reaction between the potassium salt of the acid (1a) and sodium aryloxides in methanol led only to a mixture of aryloxy-acids (6a—g) and the methoxy-acid (6h). However, these acids (6a—g) could be prepared in good yields by heating the potassium salt with sodium aryloxides in the corresponding phenols at 150—160° for 30 min. Esterification afforded the methyl esters (5e—k) identical from the reactions of the chloroester (1b) with phenols in pyridine.

Reactions of Aryloxy-acids (6; R = aryl) *in Pyridine.*—Substantial quantities of the starting acids (6; R =



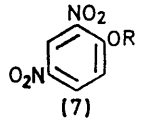
(5)

a; $R^1 = R^2$ = Ph
b; $R^1 = R^2$ = 2-MeC_6H_4
c; $R^1 = R^2$ = 2,4-$Me_2C_6H_3$
d; $R^1 = R^2$ = 4-Br-2-MeC_6H_3
e; R^1 = Me, R^2 = Ph
f; R^1 = Me, R^2 = 2-MeC_6H_4
g; R^1 = Me, R^2 = 2,4-$Me_2C_6H_3$
h; R^1 = Me, R^2 = 4-Br-2-MeC_6H_3
i; R^1 = Me, R^2 = 3-MeC_6H_4
j; R^1 = Me, R^2 = 4-MeC_6H_4
k; R^1 = Me, R^2 = 4-BrC_6H_4
l; R^1 = Me, R^2 = 2,4-Br_2-6-MeC_6H_2
m; R^1 = Me, R^2 = 2,6-$Me_2C_6H_3$
n; R^1 = Me, R^2 = 2-$MeOC_6H_4$
o; R^1 = Me, R^2 = 4-$Bu^tC_6H_4$
p; R^1 = Me, R^2 = 2-Naphthyl



(6)

a; R = Ph
b; R = 2-MeC_6H_4
c; R = 2,4-$Me_2C_6H_3$
d; R = 4-Br-2-MeC_6H_3
e; R = 3-MeC_6H_4
f; R = 4-MeC_6H_4
g; R = 4-BrC_6H_4
h; R = Me
i; R = Et
j; R = 2,4-Br_2-6-MeC_6H_2



(7)

a; R = 2-MeC_6H_4
b; R = 2,4-Br_2-6-MeC_6H_2

aryl) were recovered unchanged after heating them in pyridine at 100° for 4 h. In many cases the pyridinium salt (4a) was isolated. T.l.c. analyses revealed complete absence of even traces of aryl salicylates in all cases. In anhydrous pyridine, both *o*-tolyl (6b) and 2,4-xylyl (6c) ethers seemed to be unaffected, even though their recovery was not quantitative. The phenyl ether (6a), however, furnished besides the salt (4a), the phenyl ester (5a).

Reaction of the Methyl Ester (1b) *with Phenols.*—In contrast to the acid (1a), its ester (1b) gave the products of direct displacement, methyl 2-aryloxy-3,5-dinitrobenzoates (5; R^1 = Me, R^2 = aryl) with several of the simpler phenols and the aryl salicylates (2; R = aryl) with other relatively more hindered or acidic phenols. Minor products were also isolated in some cases and include methyl 3,5-dinitrosalicylate (2a) and 1-methylpyridinium 3,5-dinitrosalicylate (4b). These compounds, not incorporating the phenol used in the reaction, obviously arise by hydrolysis of the chloro-ester (1b). From the reaction with 4-bromo-2-methylphenol, in addition to the methyl ester (5h) and salicylate (2n), the acid (6d) and its ester (5d) were also isolated.

In a reaction with ethyl chloro-ester (1c), the aryl salicylate (2o) was obtained in reduced yield (11·4%) while the benzyl ester (1d) gave (2o) in 31·6% yield.

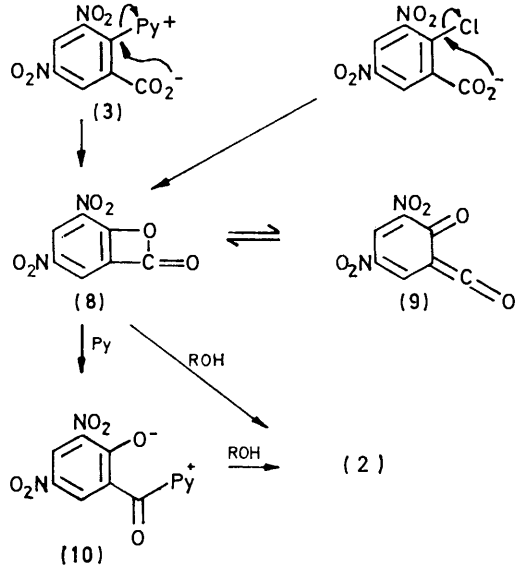
Unlike ester (1b) the isomeric methyl 4-chloro-3,5-dinitrobenzoate and the less activated methyl 2-chloro-5-nitrobenzoate furnished the expected[12] aryloxy-esters with 2,4-dibromo-6-methylphenol and there was no evidence of participation of the ester carbonyl groups in these reactions.

Reaction of the Acid (1a) *and its Methyl Ester* (1b) *with 2,4-Dinitrophenol.*—The same quaternary salt was obtained from both the acid (1a) and its methyl ester on reaction with 2,4-dinitrophenol in pyridine. The u.v. maxima at 228 (ε 36,100) and 344 nm (15,700) show that this compound is a quaternary salt of pyridine containing the dinitrosalicylate anion. Reaction of chloro-2,4-dinitrobenzene with pyridinium 3,5-dinitrosalicylate (4a) in pyridine also furnished the same compound. That this quaternary salt is 1-(2,4-dinitrophenyl)pyridinium 3,5-dinitrosalicylate (4c) is confirmed by the formation of aryl dinitrophenyl ethers (7a and b) in the reactions of the salt (4c) with phenols. These ethers were also obtained from chloro-2,4-dinitrobenzene.

DISCUSSION

Aryl and Alkyl Salicylates from the Acid (1a).—The formation of the aryl and alkyl dinitrosalicylates in all the reactions of the acid (1a) with phenols and alcohols suggests a common reactive intermediate capable of acylating these nucleophiles. The β-lactone (8), formed by an intramolecular nucleophilic displacement in the betaine (3) can be such an intermediate. Nucleophiles can add either to the lactone (8) with ring opening or to its valence-bond isomer (9) which may exist in equilibrium.

Similar lactone intermediates are involved in the thermal decomposition of benzenediazonium-*o*-carboxylate,[4] benzeneiodonium-*o*-benzoate,[5] and potassium 2-chlorobenzoate.[6] Such processes possibly occur in the thermolyses of the betaine (3) and the potassium salt of the acid (1a) in the presence of alcohols to furnish the alkyl salicylates (2; R = alkyl). In the reactions of the acid (1a) in pyridine solution, the isomeric betaine (10), formed by the addition of pyridine to the lactone (8) or the ketoketen (9) can also be the acylating agent.



There was no evidence for formation of the aryloxy-acids (6; R = aryl) [products of direct displacements on the acid (1a)] in these reactions. Such acids, as mentioned above, do not isomerise to the salicylates (2) in pyridine. Their intermediacy in the formation of aryl salicylates (2) seems unlikely.

Aryl Salicylates (2; R = aryl) *from the Chloro-ester* (1b).—The conversion of the chloro-ester (1b) into the aryl salicylates (2; R = aryl) with phenols in pyridine apparently involves hydrolysis at the aromatic carbon atom and trans-esterification of the carboxylic ester. Methyl–oxygen cleavage at some stage was evident from the fact that the reaction mixture containing (1b) and 2,4-dibromo-6-methylphenol had a strong u.v. absorption at 257 nm characteristic[7] of the *N*-methylpyridinium ion.

An initial methyl abstraction by pyridine in the pyridinium ion (13a) followed by an internal displacement in the betaine (3) formed, to give the β-lactone (8) was proposed earlier.[1] Such a mechanism is not entirely satisfactory for explaining the formation of aryl salicylates from the ester (1b), even though the

[4] R. Gomper, G. Seybold, and B. S. Schmolke, *Angew. Chem. Internat. Edn.*, 1968, **7**, 389.

[5] F. M. Beringer and S. J. Huang, *J. Org. Chem.*, 1964, **29**, 445.

[6] E. McNelis, *J. Org. Chem.*, 1963, **28**, 3188.

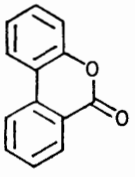
[7] P. Krumholz, *J. Amer. Chem. Soc.*, 1951, **73**, 3487.

β-lactone (8) is undoubtedly involved in the direct conversions of the acid (1a) into the aryl salicylates (2; R = aryl), as discussed already.

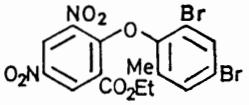
Hydrolysis by methyl–oxygen fission of the ester (5l) to the carboxylic acid (6j) and subsequent Smiles rearrangement [8] can also be considered. Methyl esters of sterically hindered acids can be hydrolysed by reaction with tertiary bases such as *N*-methylpiperidine.[9] Hydrolysis in pyridine, a much stronger carbon base than *N*-methylpiperidine,[10] does not appear to be reported. The acid (6d) in the reaction with 4-bromo-2-methylphenol, is possibly formed by such a hydrolysis of its methyl ester (5h) in pyridine.

Smiles rearrangements involving nucleophilic displacements on aromatic sites not activated by electron-withdrawing groups are known.[8] An internal displacement of the nitro-group by a carboxylate ion is invoked to explain the formation of the benzocoumarin (11) when 2-nitrobiphenyl-2′-carboxylic acid is heated in quinoline.[11]

The methyl ester (5l) obtained from the chloro-ester (1b) by reaction with sodium 2,4-dibromo-6-methylphenoxide in methanol solution, gave, on heating in pyridine with the corresponding phenol, toluene-*p*-sulphonic acid, or pyridine hydrochloride, only small quantities of the aryl salicylate (2o). The ester (5l) was susceptibile to cleavage in pyridine solution, and it could not be isolated or detected in the reactions of the chloro ester (1b), nor could it be recovered, even



(11)



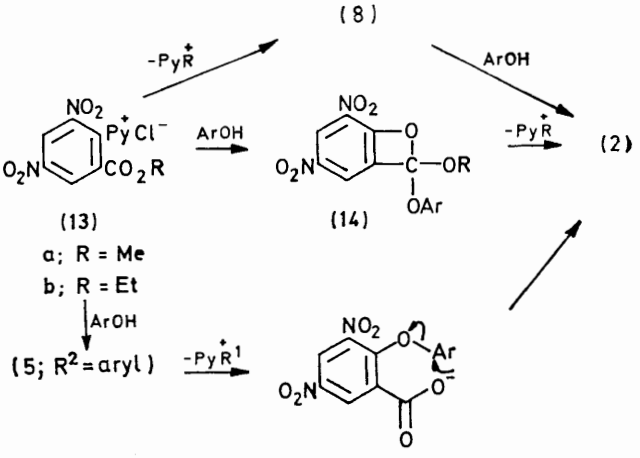
(12)

in trace amounts, from hot pyridine. From the latter experiments were isolated methyl 3,5-dinitrosalicylate (2a) and *N*-methylpyridinium 3,5-dinitrosalicylate (4b), the latter found to be readily formed by quaternization of the ester (2a) under the same conditions.

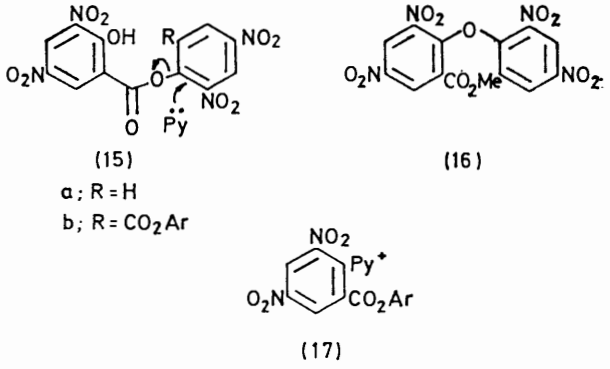
Both 2-methoxy- and 2-ethoxy-3,5-dinitrobenzoic acids (6h and i) similarly furnished the respective quaternary salts (4b and d) in pyridine. But both ethyl 3,5-dinitrosalicylate (2b) and the pyridinium salt (13b) were resistant to quaternization and no traces of the salt (4d) could be isolated.

The formation of the aryl salicylate (2o) from the ethyl ester (1c), albeit in reduced yields, implies a nucleophilic attack by pyridine on the ethyl carbon atom. It appears then that such an attack occurs in a species structurally different from the esters (2b), (13b) or (5; R^1 = Et, R^2 = aryl).

With direct substitution on the salts (13a or b) being slow with hindered or acidic phenols, nucleophilic addition to the ester carbonyl followed by an internal displacement to form the ortho-ester (14) can be significant. Attack of pyridine on the alkyl carbon in such an intermediate can open the strained four-membered ring and result in the aryl salicylate (2; R = aryl), and attack on the aromatic carbon gives a reversal to the starting materials. Attack by a phenol on the aromatic carbon may lead to the esters (5; R^1 = Me or Et, R^2 = aryl).



Formation of the Quaternary Salt.—Further reaction of an intermediate dinitroaryl dinitrosalicylate (15a), formed from both the acid (1a) and its methyl ester (1b), with pyridine leads to the salt (4c). A scission of the ether (16) to methyl dinitrosalicylate (2a) followed by a methyl–oxygen fission is also possible in the reaction of the chloro-ester (1b) with 2,4-dinitrophenol. Interchange of aryl groups in the cation, in reactions of quaternary pyridinium compounds with nitrophenols is known [12] and is thought to involve unstable polynitro-diaryl ethers.[13]

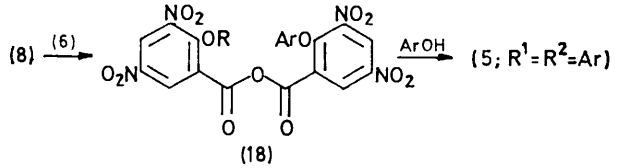


Formation of Aryl Esters (5; R^1 = R^2 = aryl).—The formation of these minor side products (5b—d)

[8] W. E. Truce, E. M. Kreider, and W. W. Brand, *Org. Reactions*, 1970, **18**, 99.
[9] M. S. Newman and H. A. Lloyd, *J. Amer. Chem. Soc.*, 1952, **74**, 2672.
[10] R. E. J. Hutchinson and D. S. Tarbell, *J. Org. Chem.*, 1969, **34**, 66.
[11] D. H. Hey, J. A. Leonard, and C. W. Rees, *J. Chem. Soc.*, 1962, 4579.
[12] (*a*) E. T. Borrows, J. C. Clayton, B. A. Hems, and A. G. Long, *J. Chem. Soc.*, 1949, S190; (*b*) G. A. Neville and R. Y. Moir, *Canad. J. Chem.*, 1969, **47**, 2787.
[13] J. F. Bunnet and R. E. Zahler, *Chem. Rev.*, 1951, **49**, 273.

from the acid (1a) can be explained by analogy with the reaction between 2,4-dinitrophenol and the chloro-acid (1a). Further reaction of the initially formed aryl dinitrosalicylates (2; R = aryl) may lead to a tetranitroaryl salicylate (15b) and/or the pyridinium ion (17). Either of these two intermediates may undergo a second nucleophilic displacement to give aryl esters of the type (5; $R^1 = R^2$ = aryl).

Alternatively, the mixed anhydride (18a) or through it, the symmetrical anhydride (18b) may be visualized as being formed by a preferential nucleophilic attack of the acid (6) on the β-lactone (8). Thus the β-lactone



(18)

a; R = H

b; R = Ar

(8) may be dehydrating the acid (6). Either of the anhydrides can react with phenols to give the aryl ester (5; $R^1 = R^2$ = aryl). Such esterification is formally similar to Brewster's method [14] of esterification of acids, the β-lactone (8) formed *in situ* playing the role of toluene-*p*-sulphonyl chloride. Though some support for this mechanism is derived from the fact that benzoic anhydride can be isolated in 26% yield, when the chloro-acid (1a) reacts with benzoic acid in pyridine, more conclusive evidence seems necessary to get a better insight into the mechanism of formation of esters (5; $R^1 = R^2$ = aryl) from the acid (1a). However, the conversion of the phenoxy-acid (6a) into the ester (5a), although in poor yield, must involve an anhydride of the above type. From the Table it can be seen that the aryl ester (5d) was also isolated in a reaction with the ester (1b). Its formation may be explained similarly by reactions of the aryl salicylate (2n) or acid (6d) with ester (1b).

EXPERIMENTAL

Pyridine (B.D.H. AnalaR) was distilled over lime and stored in tightly stoppered bottles. The grade specified as anhydrous pyridine refers to a sample redistilled over lime just before use. 2-Chloro-3,5-dinitrobenzoic acid,[15] its methyl and ethyl esters,[16] methyl 4-chloro-3,5-dinitrobenzoate,[15] methyl 2-chloro-5-nitrobenzoate,[17] 3,5-dinitrosalicylic acid,[18] its methyl and ethyl esters,[19] 4-bromo-2-methylphenol,[20] 2,4-dibromo-6-methylphenol,[21] and 2,3,6-tribromo-4-methylphenol,[22] were all prepared according to published procedures.

Reaction of Acid (1a) *with Pyridine.*—A mixture of the chloro-acid (1a) (2·46 g) and pyridine (4 ml), after standing for 10 min at room temperature, was diluted with ethanol. The precipitated solid gave 3,5-dinitro-2-(1-pyridinio)-benzoate (3),[2] m.p. 182—184°, raised to 186° (decomp.), (from water), (2·07 g, 72%), $\nu_{max.}$ (KBr) 1660 cm^{-1}, $\lambda_{max.}$ (EtOH) 231 nm (ε 19,400) (Found: C, 49·6; H, 2·6; and N, 14·3. Calc. for $C_{12}H_7N_3O_6$: C, 49·8; H, 2·4; N, 14·5%).

The filtrate was evaporated and the residue was dissolved in acetone. Concentration gave *pyridinium 3,5-dinitrosalicylate* (4a) (121 mg, 4%), as yellow crystals, m.p. 163—164° (from EtOH), $\nu_{max.}$ (KBr) 1710 cm^{-1}, $\lambda_{max.}$ (EtOH) 340 nm (ε 12,300) (Found: C, 46·4; H, 3·2; N, 13·6. $C_{12}H_9N_3O_7$ requires: C, 46·9; H, 2·9; N, 13·6%). The salt (4a) could also be obtained by mixing equimolar amounts of pyridine and 3,5-dinitrosalicylic acid in ether.

Hydrolysis of the Betaine (3) *and the Potassium Salt of Acid* (1a).—The betaine (3) (2·0 g) was heated in pyridine on a water-bath for 4 h. Pyridine was removed by distillation and the residue was washed with ether and then digested with hot water. From the aqueous solution the salt (4a) (460 mg, 22%) was obtained after concentration and crystallization.

Ethanolic potassium hydroxide (1 equiv.) was added dropwise to a stirred solution of the acid (1a) in ethanol. The precipitated potassium salt was washed with alcohol and dried. The potassium salt (2 g) was heated with pyridine (15 ml) for 4 h. The residue after distillation of pyridine was washed with ether. The insoluble material was continuously extracted with benzene to give the salt (4a) (1·23 g. 57%).

Thermal Decomposition of the Betaine (3).—(*a*) *In alcohols.* The betaine (3) (400 mg) was heated with methanol (6 ml) in a sealed tube at 100° for 7 h. Methyl 3,5-dinitrosalicylate (2a) (112 mg, 32·7%), m.p. 126—127°, was precipitated on acidification of the solution with 1 drop of conc. HCl.

The ethyl ester (2b) (26 mg, 10%), m.p. 97—98°, was obtained from (3) (289 mg) after heating in ethanol (5 ml) at 140° for 6 h.

(*b*) *In* p-*cymene.* To a mixture of *p*-cymene (50 ml) and ethanol (5 ml) kept at 150—160° in an oil-bath, betaine (3) (1·43 g) was added in portions over 30 min. After a further 30 min at this temperature, the clear solution was decanted off. Ethyl ester (2b) (478 mg, 37·6%) was isolated from this solution by washing with sodium hydrogen carbonate solution and subsequent acidification.

Allyl ester (2e) (650 mg, 23·4%) was obtained in a similar fashion, from (3) (3·0 g), allyl alcohol (7·5 ml), and *p*-cymene (100 ml).

Thermal Decomposition of the Potassium Salt of (1a).—A solution of the salt (250 mg) in methanol (5 ml) was heated in a sealed tube at 135° for 20 h. The solution was concentrated and cooled to give the methyl ester (2a) (64 mg, 30%).

Reaction of the Acid (1a), *its Potassium Salt, and Betaine* (3) *with* 2,4-*Dibromo-6-methylphenol.*—A mixture of the acid (1a), or its potassium salt or betaine (3), and 2,4-dibromo-6-methyl phenol (0·01 mol each) was heated in an oil-bath (~100°) with pyridine (20 ml) for 4 h. The residue after removal of pyridine was washed with ether (3 ×

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[22] Th. Zincke and K. Wiederhold, *Annalen*, 1901, **320**, 205.

50 ml). The ethereal solution contained mainly the unchanged phenol (t.l.c.). The insoluble solid was continuously extracted with benzene. Aryl salicylate (2o) was preferentially extracted. The salt (4a) was obtained on further extraction. The yields of the aryl salicylate (2o) and the salt (4a) were; from the acid (1a) 0·84 and 44·7, and 5·5 and 63·5, from its potassium salt, 2·74 and 84, and from the betaine 3·1 and 67·4%, respectively.

Hydrolysis of the Aryl Salicylate (2o) *in Pyridine.*—Aryl salicylate (2o) (960 mg) was heated with pyridine (4 ml) on a water-bath for 3 h. The mixture of the phenol, aryl salicylate, and the salt (4a), was separated as in the previous experiment to furnish the salt (4a) (120 mg, 15·4%) and unchanged ester (2o) (78·7%).

Reaction of Alcohols and Phenols in Anhydrous Pyridine with Acid (1a).—A stirred mixture of the acid, the phenol or alcohol (0·01 mol each; 2—3 ml of C_2—C_4 alcohols), and anhydrous pyridine (20 ml) was heated in an oil-bath (~100°) for 4 h in a system closed with a rubber balloon. The residue left after removal of pyridine was washed with ether, and the ether-insoluble material was continuously extracted with benzene. From the benzene extracts, aryl and alkyl salicylates (2) and the pyridinium salt (4a) were obtained. Additional quantities of alkyl salicylates could also be obtained from the ether washings. The ether solution from the reactions with phenols contained mainly the unchanged phenols with traces of pyridine. From the reactions with *o*-cresol, 2,4-dimethylphenol, and 4-bromo-2-methylphenol, the ether solutions on concentration and crystallization afforded small quantities of the aryl esters (5b—d).

The yields of products are given in Table 1, and m.p spectral, and analytical data of compounds (2c—x) and (5b—d) are listed in Supplementary Publication No. SUP 20841 (7 pp.).*

Aryl-3,5-Dinitrosalicylates (2) *from 3,5-Dinitrosalicylic Acid.*—A mixture of 3,5-dinitrosalicylic acid (2·28 g, 0·01 mol), PCl_5 (2 g), and petroleum (4 ml) was heated under reflux for 3·5—4 h.[3] The petrol solution was decanted off and the residue was washed with petrol (2 × 2 ml). The insoluble material was digested in benzene. This benzene solution was heated under reflux with phenol or *o*-cresol (0·01 mol) and a drop of pyridine for 2 h. The benzene solution was washed with water and dried. The residue after distillation of benzene furnished the corresponding aryl salicylate (2k) (36·7%) or (2l) (32·3%).

The acid chloride left on concentration of its benzene solution was treated with 2,4-dibromo-6-methylphenol (0·01 mol) and pyridine (3·5 ml). After 15 min at room temperature the mixture was diluted with ethanol and the ethanol-insoluble solid was crystallized to get (2o) (69·7%).

The pyridine solution from the reaction with 2,3,6-tribromo-4-methylphenol was washed with petroleum to leave a gummy material which on crystallization with ethyl acetate furnished ester (2p) (57·6%).

The mixture of the acid chloride, 2,4-di-t-butyl-6-methyl phenol, and pyridine was heated for 2 h. Pyridine was removed by distillation and the residue extracted with chloroform. The extract, after washing with water, dilute HCl, and water, and drying was concentrated. The gummy material obtained was crystallized from methanol to give (2x) (18·6%).

* For details of Supplementary Publications see Notice to Authors No. 7 in *J.C.S. Dalton*, 1972, Index Issue (items less than 10 pp. are supplied as full size copies).

2-Aryloxy-3,5-dinitrobenzoic Acids (6).—To a mixture of sodium phenoxide in phenol (prepared by dissolving sodium in phenol), the potassium salt of (1a) (slightly less than 1 equiv.) was added and the mixture was heated in an oil-bath (150—160°) for 30 min. The dark mixture was diluted with water and extracted with ether. The aqueous solution was acidified and the acid (6) was purified by extraction with ether, washing with sodium hydrogen carbonate solution, and acidification with conc. HCl to precipitate the crystalline acid. With *o*-cresol, the corresponding acid (6b) was obtained crystalline after chromatography over silica gel. The yields of the acids were: (6a) 100, (6b) 33·3, (6c) 47·4, (6e) 47·1, and (6f) 85·6%. The bromo-acids (6d) 100%, and (6g) 61·5% were obtained on bromination of acids (6a) and (6b) in acetic acid at room temperature for 2—3 h. The physical data of compounds (6a—g) are listed in Supplementary Publication No. SUP 20841 (7 pp.).*

Methyl 2-Aryloxy-3,5-dinitrobenzoates (5; R^1 = Me).—The acids (6a—g) on esterification in methanol solution saturated with hydrogen chloride furnished the corresponding methyl esters (5e—k) in yields ranging from 80 to 100% (physical data in SUP No. 20841 *).

Aryl 2-Aryloxy-3,5-dinitrobenzoates (5b) *and* (5c).—A mixture of acid (6b) (600 mg) thionyl chloride (3 ml), benzene (30 ml), and a drop of pyridine was heated with stirring for 3·5 h. Excess of thionyl chloride was removed by repeated distillation with benzene. The acid chloride without further purification was heated with *o*-cresol (300 mg) in benzene solution for 1 h. The benzene solution was worked up for neutral material to give the ester (5b (601 mg, 78%). By a similar procedure, ester (5c) (71·2%) was obtained from the acid (6c).

Reaction of Aryloxy acids (6) *with Pyridine.*—The aryloxy-acids (6) (0·005 mol) were heated in pyridine (10 ml) on a water-bath for 4 h. The residues after removal of pyridine were washed with ether. The ether solutions yielded the unchanged acids and the corresponding phenols. Ether-insoluble material was crystallized to get the pyridinium salt (4a). T.l.c. analysis of the products did not indicate the presence of aryl salicylates (2). The results are given in Table 2.

TABLE 2

Reactions of 2-aryloxy-3,5-dinitrobenzoic acids (6) with pyridine

Compound	Recovery of (6) (%)	Py^+ salt (4a) (%)
(6a)	65·6	5·4
(6b)	62·4	
(6c)	66·7	2·7
(6d)	52·9	16·3
(6e)	52·6	12·4
(6f)	61·8	13·2
(6g)	14·0	50·7

In anhydrous pyridine, under similar conditions, recovery of acids (6b) and (6c) were 84·9 and 86·9%. The salt (4a) could not be isolated in these experiments. The recovery of acid (6a) in a similar experiment was 68·4%. The ether solution freed of acid material in this experiment furnished the aryl ester (5a) in 4·1% yield. The salt (4a) was isolated in 14·4% yield.

Reaction of Chloro-ester (1b) *with Phenols in Pyridine.*—An equimolar mixture of the phenol and the ester (1b)

(0·01 mol each) in pyridine (20 ml) was heated on a water-bath or in an oil-bath (100°) for 4 h. The reaction mixtures with phenol, *o*-, *m*-, and *p*-cresols, 2,6-dimethylphenol, 2-methoxyphenol, 4-t-butylphenol, and 2-naphthol were poured onto ice. The crystalline aryloxy benzoates (5e, f, i, j, and m—p) separated and were crystallized from appropriate solvents. The aqueous solutions after the separation of these esters, when concentrated to dryness left mixtures possibly of hydrolytic products (4a and b).

With 2,4-dimethylphenol, the mixture after dilution with cold water was extracted with ether. The extract was washed with dil. HCl, water, dried, and concentrated to give (5 g). From the aqueous solution, the methylpyridinium salt (4b) was obtained on concentration and crystallization.

Separation of products was difficult in the reaction with 4-bromophenol even though aryl salicylate (2t) was present (t.l.c.). Only the ester (5k) could be isolated in pure condition by extractive work-up of the reaction mixture with ether, followed by chromatography over silica gel.

From the reaction with 4-bromo-2-methylphenol, pyridine was removed by distillation and the residue shaken with 2 × 40 ml portions of ether. Aryl salicylate (2n) was obtained from the ether-insoluble material on continuous extraction with benzene. The ether solution was washed with dil. HCl, water, sodium hydrogen carbonate, water, and dried. Acidification of the sodium hydrogen carbonate washings furnished the acid (6d). The methyl ester (5h) crystallized out from the concentrated ether solution. From the mother liquor after separation of (5h), on chromatography over silica gel, the aryl ester (5d) and an additional quantity of (5h) were isolated.

In the reaction with 2,4-di-t-butyl-6-methylphenol, the residue after distillation of pyridine was extracted with ether and the extract was washed with dil. HCl and water, and dried. The gummy material was transferred to a column of silica gel and eluted with petroleum–benzene (1 : 1) to obtain crystalline ester (2x).

The residues left after distillation of pyridine from the reactions with 2,4-dibromo-6-methylphenol, 2,4-dichlorophenol, and ethyl 5-bromosalicylate were washed with ether. The ether-insoluble solids were continuously extracted with benzene to give the aryl salicylates (2o, q, and r). The ether solutions contained only the unchanged phenols.

From the reaction with 2,3,6-tribromo-4-methylphenol, the residue, freed of pyridine, was washed with conc. HCl and was repeatedly crystallized from acetone to give (2p).

In different experiments with 2,4-dibromo-6-methylphenol the yields of the aryl salicylate (2o) varied from 40 to 85%. In one experiment the salt (4b) was isolated in as high a yield as 21·8%. The mixture from one of the experiments after dilution with water showed a strong u.v. absorption at 258 nm when balanced against a pyridine blank solution. The results are listed in Table 1 and spectral and analytical data on all these compounds in Supplementary Publication No. SUP 20841.†

Reaction of Ethyl Ester (1c) *with* 2,4-*Dibromo*-6-*methylphenol*.—The ester (1c) (5·49 g) when treated with 2,4-dibromo-6-methylphenol (5·32 g) and pyridine (25 ml) (1·06 g, 11·1%) under similar conditions afforded the aryl salicylate (2o).

Reactions of the Acid (1a) *and Ester* (1b) *with* 2,4-*Dinitrophenol*.—A mixture of the acid (1a) (2·46 g), 2,4-dinitrophenol (1·9 g), and anhydrous pyridine (20 ml) was heated in an oil-bath (100°) for 3 h. The residue after removal of pyridine was stirred with water (50 ml). The separated solid was crystallized from aqueous acetone to give 1-(2,4-*dinitrophenyl*)*pyridinium* 3,5-*dinitrophenylsalicylate* (4c) (2·13 g, 45·1%), m.p. 193—194°. The same salt was obtained in 69·3% yield from the ester (1b) under similar conditions, $\lambda_{max.}$ (EtOH) 228 (ε 36,100) and 344 nm (15,700) (Found: C, 45·8; H, 2·7; N, 14·8. $C_{18}H_{11}N_5O_{11}$ requires C, 45·7; H, 2·3; N, 14·8%). The salt (4c) was also prepared by heating an equimolar mixture of 2,4-dinitrochlorobenzene and the salt (4a) in pyridine for 30 min and diluting with water. The yield of the quaternary salt (4c) separated was 89%.

Aryl 2,4-*Dinitrophenyl Ethers* (7a *and* b).—A mixture of the salt (4c) (3·7 g), *o*-cresol (1·5 g), and pyridine (20 ml) was stirred on a water-bath for 4 h and then poured onto ice. Separated diaryl ether (7a) was collected (1·24 g) (57—85%), m.p. 94—94·3° (from aq. EtOH) (lit.,[23] 90°), $\lambda_{max.}$ (EtOH) 290 nm (ε, 11,600) (Found: C, 56·9; H, 4·0; N, 10·4. Calc. for $C_{13}H_{10}N_2O_5$: C, 56·9; H, 3·6; N, 10·2%).

The mixture with 2,4-dibromo-6-methylphenol was extracted with ether to give 2,4-*dibromo*-6-*methylphenyl* 2,4-*dinitrophenyl ether* (7c) (31·1%), m.p. 92—93°, $\lambda_{max.}$ (EtOH) 281 nm (ε 13,300) (Found: C, 36·3; H, 2·2; N, 6·8. $C_{13}H_8Br_2N_2O_5$ requires C, 36·1; H, 1·8; N, 6·5%).

Both the ethers (7a and b) were also obtained from 2,4-dinitrochlorobenzene.

Methyl 2-(2,4-*Dibromo*-6-*methylphenoxy*)-3,5-*dinitrobenzoate* (5l).—To a solution of the chloro-ester (1b) (4·4 g) in methanol (50 ml) kept under reflux, a solution of 2,4-dibromo-6-methylphenol (4·4 g) and sodium hydroxide (660 mg) in water (10 ml) was added with stirring. After 1 h, methanol was removed and the residue extracted with ether. The diaryl ether (5l), m.p. 96—97° (43·2 g, 39·5%) was obtained when the ether extract was worked up for neutral material. Yields in different experiments varied from 26 to 39%.

Reaction of the Ester (5l) *in Pyridine with* 2,4-*Dibromo*-6-*methylphenol, Toluene*-p-*sulphonic Acid, and Pyridine Hydrochloride*.—The ester (5l) was heated in pyridine with equimolar quantities of the dibromocresol, toluene-*p*-sulphonic acid, or pyridine hydrochloride for 4 h. Residues after removal of pyridine were washed with ether. Ether solutions were found to contain mainly the phenol, and ester (5l) could not be detected. Both aryl and methyl salicylates were extracted with benzene from the ether insoluble solid and were separated by fractional crystallization. The salt (4b) remained unextracted.

The yields of aryl salicylate were 4·6, 4·2, and 2·1%, respectively. The salt (4b) was isolated in 27·9 and 39·2% in the experiments with the phenol and pyridine hydrochloride. Methyl salicylate (2a) (18·6%) was isolated only in the experiment with pyridine hydrochloride.

1-*Methylpyridinium* 3,5-*Dinitrosalicylate* (4b).—Methyl 3,5-dinitrosalicylate (2a) (1 g) was heated with pyridine (5 ml) on a water-bath for 3·5 h. The residual solid after removal of pyridine was crystallized from ethyl acetate–acetone to yield the *quaternary salt* (4b) (740 mg, 55·8%), m.p. 183·6—184·8°, $\nu_{max.}$ (KBr) 1685 cm^{-1}, $\lambda_{max.}$ (EtOH) 258 (ε 9400) and 340 nm (12,300), δ[$(CD_3)_2SO$] 4·5 (3H, s,

† See footnote p. 2954.

[23] R. W. Bost and F. Nicholson, *J. Amer. Chem. Soc.*, 1935, **57**, 2368.

MeN^+), 8·0—8·83 (5H, m, pyridine protons), and 9·08 and 9·16br (2H, ArH) (Found: C, 48·9; H, 4·0; N, 13·2. $C_{13}H_{11}N_3O_7$ requires C, 48·6; H, 3·6; N, 13·1%). 2-Methoxy-3,5-dinitrobenzoic acid [15] (6h) on heating with pyridine for 1·5 h afforded (4b) in 66·3% yield.

1-*Ethylpyridinium* 3,5-*Dinitrosalicylate* (4d).—A solution of 2-ethoxy-3,5-dinitrobenzoic acid [15] (6i) (1 g) in pyridine (5 ml) was heated for 2 h and pyridine was distilled off. On crystallization from ethyl acetate–ethanol, the solid residue furnished the *salt* (4d) (770 mg, 58·8%), m.p. 129—129·5°, $\nu_{max.}$ (KBr) 1690 cm^{-1}, $\lambda_{max.}$ (EtOH) 258 (ε, 10,900) and 340 nm (12,500) (Found: C, 50·1; H, 4·3; N, 12·0. $C_{14}H_{13}N_3O_7$ requires C, 50·1; H, 3·9; and N, 12·5%).

Benzyl 2-*Chloro*-3,5-*dinitrobenzoate* (1d).—A mixture of 2-chloro-3,5-dinitrobenzoic acid (1a) (5 g), thionyl chloride (10 ml), dry benzene (70 ml) and pyridine (one drop) was refluxed for 3 h. Benzene and excess of thionyl chloride were removed by distillation. The acid chloride without further purification was heated under reflux with benzyl alcohol (5 ml) in benzene (50 ml) for 1·5 h. The benzene solution was washed with water, dilute sodium hydrogen carbonate solution, and water and dried. The residue left after removal of benzene was crystallized from ethanol to give the *ester* (1d) (6·16 g, 92%), m.p. 106·8—108°, $\nu_{max.}$ (KBr) 1720 cm^{-1}, δ ($CDCl_3$) 8·58—8·78 (2H, q, *J* 3 Hz, ArH), 7·23 (5H, s, ArH), and 5·43 (2H, s, $PhCH_2O$) (Found: C, 50·3; H, 3·0; N, 8·3. $C_{14}H_9ClN_2O_6$ requires C, 49·9; H, 2·7; N, 8·3%).

Reaction of the Benzyl Ester (1d) *with* 2,4-*Dibromo*-6-*methylphenol in Pyridine*.—The chloro-benzyl ester (1d) (3·14 g) and phenol (2·66 g) in pyridine (20 ml) were heated (100°) for 4 h. Pyridine was removed, the residue washed with ether, and ether-insoluble solid extracted with benzene to get the aryl salicylate (2o) (1·42 g, 30·7%).

Reaction of Methyl 4-*Chloro*-3,5-*dinitrobenzoate with* 2,4-*Dibromo*-6-*methylphenol in Pyridine*.—A mixture of the chloro-ester (2·6 g) and the dibromocresol (2·66 g) in pyridine (20 ml) was heated (95—100°) for 4 h. The residue after distillation was extracted with chloroform. The extract was washed with dil. HCl, water, and dried, and yielded *methyl* 4-(2,4-*dibromo*-6-*methylphenoxy*)-3,5-*dinitrobenzoate* on evaporation, m.p. 164·5—165·5 (from ethanol) (986 mg, 20·5%), $\nu_{max.}$ (KBr) 1730 cm^{-1}, δ ($CDCl_3$) 8·58 (2H, s, nitro-ring ArH), 7·2—7·5br (2H, bromo-ring ArH), 4·0 (3H, s, OMe), and 2·33 (3H, s, Ar*Me*) (Found: C, 37·1; H, 2·3; N; 6·1. $C_{15}H_{10}Br_2N_2O_7$ requires C, 36·7; H, 2·0; N, 5·7%).

Reaction of Methyl 2-*Chloro*-5-*nitrobenzoate with* 2,4-*Dibromo*-6-*methylphenol in Pyridine*.—An equimolar mixture of the chloro-ester (2·15 g) and the bromocresol (2·67 g) in pyridine (10 ml) was heated (100°) for 4 h. The dark residue after removal of pyridine was extracted with ether, and the extract was washed with dil. HCl, water, and dried. Removal of ether left a gummy material which was chromatographed over silica gel. Elution with petroleum afforded the unchanged phenol (1·09 g, 40·8%). Further elution with petroleum–benzene furnished the starting chloro-ester (96 mg, 4·5%), and then *methyl* 2-(2,4-*dibromo*-6-*methylphenoxy*)-5-*nitrobenzoate* (498 mg, 11·2%), m.p. 143·2—144·2 (from ethanol), $\nu_{max.}$ (KBr) 1730 cm^{-1}, $\lambda_{max.}$ (EtOH) 293 nm (ε 8500), δ ($CDCl_3$) 8·85 (1H, d, nitro-ring ArH). 7·33—8·35 (3H, m, nitro- and bromo-ring ArH) 4·01 (3H, s, OMe), and 2·21 (3H, s, Ar*Me*) (Found: C, 40·9; H, 3·0; N, 3·6. $C_{15}H_{11}Br_2NO_5$ requires C, 40·4; H, 2·5; N; 3·1%).

Reaction of the Acid (1a) *with Benzoic Acid in Pyridine*.—A mixture of the acid (1a) (2·46 g) and benzoic acid (2·44 g) in anhydrous pyridine (20 ml) was heated (100°) for 3 h. The residue after removal of pyridine was extracted with ether (200 ml), and the extracts were washed with water, dilute sodium hydrogen carbonate, again with water, and dried. Removal of ether furnished gummy material which was crystallized to give benzoic anhydride, m.p. and mixed m.p. 41—42° (from petroleum) (lit.,[24] 43°) (580 mg, 25·7%). The $NaHCO_3$ washings were acidified to yield benzoic acid, m.p. 121—122° (320 mg, 13·1%). The ether-insoluble solid was continuously extracted with benzene to furnish the salt (4a) (946 mg, 30·9%).

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